



Library  
U. S. Naval Postgraduate School  
Monterey, California













THE PENNSYLVANIA STATE COLLEGE  
Department of Mechanical Engineering

USE OF INDICATOR DIAGRAMS IN DETERMINING CONDENSATION  
IN A DIESEL ENGINE

A Thesis

By

LIEUTENANT J. B. LONGSTAFF, U. S. NAVY

AND

LIEUTENANT (junior grade) F. R. LONGSTAFF, U. S. NAVY

Submitted in partial fulfillment  
for the degree of  
MASTER OF SCIENCE

June, 1952

REVIEW OF THE LITERATURE ON  
POLY(URIDYLIC ACID) IN MAMMALS

This document contains 96 references  
28 tables and 14 figures.

INTRODUCTION

1

THE URIDYLIC ACID TRANSPORT  
SYSTEM

THE URIDYLIC ACID TRANSPORT SYSTEM

TRANSPORT ANALYSIS BY DIFFUSION  
IN MEMBRANE AND  
CHLOROPHYLL A

ERIC VANDEN

Department of Biochemistry  
University of California  
Berkeley, California 94720

Object. The object of this investigation was to study the effects of various sizes of orifices in the fuel injection nozzle and pre-combustion chambers upon the combustion in a multicylinder compression ignition engine.

For purposes of comparison a series of economy runs were made and indicator cards and offset diagrams were taken under such conditions. The effects of these changes were analyzed to show their influence upon the resulting combustion in the engine cylinder.

Apparatus and Results. A marine type, vertical, four cylinder, four stroke cycle Mill Diesel engine, having a 5 inch bore and a 7 inch stroke was used during the investigation. This engine is of the compression ignition solid injection, antechamber type, having a compression ratio of 17.6.

The power was absorbed by a water-cooled proxy brake having a bend length of 5.15 feet and a zero weight of 8 pounds. The brake load was measured on a Tolomatic springless scale. The over absorbing capacity of this brake limited the investigator to power loads below the rated power of the engine. Operation at high loads was so erratic that performance runs were limited to about 35 BHP.

Circulating water was furnished by the college mains leading into the circulating water pipe attached to the engine, but dependence was not placed on the pump for pressure. The rate of flow of the circulating water was

of our institutions that it might well demand  
that half an hour's time be given to study and talk  
about these various movements in culture and  
politics, and that independent thought and a  
process of action should occupy as much time  
as possible. But this is about as far as we can  
go. For most of us, especially those who have  
not been exposed to many new experiences or  
thoughts, would find it difficult to  
comprehend such a revolution.  
And the intellectual wings cannot bear a weight  
such as this, and could easily break. And still the nation  
and civilization will not change save through  
a violent revolution. — And so, you might say, we  
must be given more time  
and more opportunity to think and to  
discuss what is important. — In general, more time  
and more opportunity to think and to discuss is the  
most effective method of improving our  
nation and civilization. — As revolution has  
been used only to indicate sudden and extreme  
changes in the form of government, there may  
be some who believe that better illustrations  
of revolution and other political and social changes  
are those in which there is no violence and  
no death and no destruction and pain, and  
very little disturbance and the most in order and  
regularity.

controlled by a throttle valve ahead of the pump so as to maintain a circulating water temperature of 120 degrees F. at outlet.

Iron-constantan thermo-couples, manufactured by the Brown Instrument Company were installed in the exhaust manifolds between the exhaust valves and the exhaust header. The exhaust temperatures were balanced to within 5 degrees F. of each other and in addition the load balance between the cylinders was checked by removing the exhaust injection ports and observing the relative intensity of sound of each exhaust.

In conducting this investigation it was decided to run the engine at 800 R.P.M., the rated full load speed. At this speed the engine operated more smoothly than at lower speeds. Prior to taking any data the engine was run for half an hour to allow thermal equilibrium to obtain. Tests were made starting with the lower loads, between runs time was allowed for the engine to warm up under the next load condition before the following run was made. Outlet circulating water temperature was maintained at 120 degrees F. throughout the investigation. Lubricating oil pressure was maintained at 75 pounds.

The injection advance device was not calibrated in such fashion as to permit advancing the injection by any predetermined number of degrees, but by means of a series

and the power held by police under section 4 of the Act  
will not be consistent with subsection 1(1) of the Act.  
Therefore, the Act does

not provide for a meaningful administrative

process for the review of specific enforcement  
actions and provides no specific enforcement  
procedures or mechanisms to correct erroneous  
or discriminatory decisions and to afford due process and  
administrative review to those who have been  
subjected to discriminatory enforcement actions and remedial  
or corrective actions and without an effective and timely

process from the time  
of issuance, over 60 days, of a final administrative decision  
to correct discriminatory practices and to allow sufficient time for  
any administrative appeal to the Board of Inquiry to be  
conducted and for the Board of Inquiry to issue its decision  
and grant relief and to correct discriminatory practices and  
afford due process and to correct discriminatory practices and  
allow sufficient time for the Board of Inquiry to issue its decision  
and grant relief and to correct discriminatory practices and  
allow sufficient time for the Board of Inquiry to issue its decision  
and grant relief and to correct discriminatory practices and  
allow sufficient time for the Board of Inquiry to issue its decision  
and grant relief and to correct discriminatory practices and

allow sufficient time for the Board of Inquiry to issue its decision  
and grant relief and to correct discriminatory practices and  
allow sufficient time for the Board of Inquiry to issue its decision  
and grant relief and to correct discriminatory practices and

of holes drilled in a strip of iron which was then bolted to the engine housing it was possible to maintain any desired advance and return to the same setting at will.

Indicator cards were taken by means of the Bureau of Standards balanced diaphragm type of indicator.

This indicator (NACA #107 - Reference 1) consists essentially of the following elements: a water cooled pressure element, attached to and in communication with the engine cylinder space; a timer, connected on the end of the crankshaft and rotating at crankshaft speed; and the coordinating apparatus, consisting of source of pressure, gages for measuring pressure, and an electrical circuit for indicating balanced pressures.

The pressure element, Plate XIII, was in this investigation installed in the relief valve casting, communicating directly with the combustion space. A series of small water-cooled holes conduct the cylinder gases to the under side of the steel diaphragm; the other side of the diaphragm is subjected to a pressure, by carbon dioxide, the amount of which is controlled and measured by the operator at the manifold. When the pressure on the cylinder side of the diaphragm exceeds that on the upper side, the diaphragm is forced against an insulated electrode in the top of the element, closing an electric circuit.

which may well prove to be the best way to do this. We have had to do this because of course, we do not know what will happen now, nor do we know how many more months will be spent at least until some kind of a deal.

Another important reason would be because it is essential to have a clear understanding of what is happening.

Other factors which would affect the negotiations are the political situation in the country, economic conditions and the international situation. These factors are very important, because they can affect the outcome of the negotiations.

Finally, another factor which would affect the negotiations is the personal relationship between the two sides.

There are many other factors which would affect the negotiations, such as the political situation in the country, economic conditions and the international situation.

All these factors are important, but the most important factor is the personal relationship between the two sides.

With all these factors in mind, it is clear that the negotiations will be successful if both sides work together and try to find a common ground. This is the best way to do this, because it is the only way to ensure that the negotiations will be successful.

The timer, Plates XXIV and XXV, is in series with the electric circuit mentioned, and forms another break in it. A small copper insert in a bakelite-like base connects with a stationary brush and each revolution for a brief interval. The area of contact is one square. The brush is adjustable throughout the entire stroke, and its setting is read by means of a degree scale on the outer periphery.

The coordinating apparatus (7) consists of a manifold to which are connected three gauges, one reading from 10<sup>-8</sup> of mercury vacuum to 15 lbs. per sq. in. pressure, one, 0 to 100 lbs. per sq. in., and one, 0 to 1000 lbs. per sq. in. pressure, respectively. One end of this manifold is connected to a bottle containing liquid carbon dioxide, and the other to the pressure element. A vent and an aspirator connection complete the manifold. Adequate valves are installed to allow adjustment of any pressure in the manifold, and choice of gases suitable to the portion of the cycle being studied.

The electrical system is shown schematically in Plate XXVI. Two dry cells in series with a low resistance telephone receiver, the pressure element, and the timer form the essential parts of the circuit. When both the contact breakers are closed, a click is heard in the telephone; another click is heard as the circuit is opened.

also some of the people you would meet will be very interesting. You can always expect to find some interesting and unusual people in the world and you never know what you might find. You may also come across some people who are not very nice but you can always find some good ones too. You can also meet some nice people who are very kind and helpful at times and you will be able to make new friends there.

• • •

There are many different ways to travel and each one has its own unique advantages and disadvantages. One way is to travel by car which is very practical and can be very comfortable. Another way is to travel by bus or train which is also very practical and can be very comfortable. You can also travel by plane which is very fast and can get you to your destination quickly. You can also travel by boat which is very relaxing and can be very enjoyable. You can also travel by bicycle which is very healthy and can be very fun. You can also travel by motorcycle which is very fast and can be very exciting. You can also travel by bus or train which is very practical and can be very comfortable. You can also travel by plane which is very fast and can get you to your destination quickly. You can also travel by boat which is very relaxing and can be very enjoyable. You can also travel by bicycle which is very healthy and can be very fun. You can also travel by motorcycle which is very fast and can be very exciting.

• • •

There are many different ways to travel and each one has its own unique advantages and disadvantages. One way is to travel by car which is very practical and can be very comfortable. Another way is to travel by bus or train which is also very practical and can be very comfortable. You can also travel by plane which is very fast and can get you to your destination quickly. You can also travel by boat which is very relaxing and can be very enjoyable. You can also travel by bicycle which is very healthy and can be very fun. You can also travel by motorcycle which is very fast and can be very exciting. You can also travel by bus or train which is very practical and can be very comfortable. You can also travel by plane which is very fast and can get you to your destination quickly. You can also travel by boat which is very relaxing and can be very enjoyable. You can also travel by bicycle which is very healthy and can be very fun. You can also travel by motorcycle which is very fast and can be very exciting.

Refinements in the circuit consist of a variable condenser for varying the intensity of the click to suit the observer, and two switches by which either the timer or the pressure element can be short circuited to check the operation of the other.

The procedure was as follows:

1. With the engine running, and the indicator properly connected, the timer was set to any desired crankshaft angle.

2. The operator then listened on the phone. If a click of the same frequency as the sound of the shift was heard, it indicated that the pressure in the manifold was less than the cylinder pressure for the particular point in the cycle for which the timer was set, and the pressure was increased in the manifold until the clicking ceased. The base pressure at which the clicking ceased, i.e., when the diaphragm was just held away from the electrode was recorded as the cylinder pressure for that point.

3. The timer periphery is graduated in two degree increments, and points were selected around the cycle to give the desired spacing when plotted on pressure-volume coordinates. For the range from twenty degrees before top dead center to twenty degrees after top dead center, points were taken every two degrees for plotting of offset

the most popular with account books and oil sketches. Their  
use at first did not last, probably because they  
are not much more durable than paper and were  
not used in England. Now we can hardly believe

that such a difference  
exists between oil and watercolor and  
we may add one question and leave the rest to  
you. Is it true that oil paint will give more permanence  
than water color?

We have seen some oil painting and believe that  
it must be done in a patient and deliberate  
manner so that one has time to plan his  
work and will always measure and paint with care  
and love. But water color gives such energy and life  
and movement, and because it is so easy to do, it  
is often done in a hasty and haphazard way.  
And here comes the question again: Is it  
better to paint slowly and carefully or  
more quickly and easily?

There is no question of speed, for water color  
is not a slow medium. It is a quick and  
delightful medium, but it does not apply  
as well to large spaces and does not  
allow us to paint over our mistakes  
as easily as oil paint. So we must either

cards of ignition and combustion.

4. For getting points on the suction and exhaust strokes, the pressure at which the double-click faded into the single click was recorded. Since the timer travels through 360 degrees, and the cycle lasts 720 crank degrees, points on the exhaust and suction strokes were on the same timer settings as homologous points on the compression and expansion strokes, respectively. Then the manifold pressure was below that of the suction or exhaust line, as the case might be, the pressure bypass circuit was closed by the diaphragm valve for each revolution of the timer, giving a pair of clicks for each revolution of the shaft, or a sound of twice the frequency of crank-shaft speed (in the first case contact was made on alternate revolutions). As the observer becomes accustomed to the frequency of the normal clicks, he will notice promptly the doubling in occurring when passing through the pressure corresponding to the suction or exhaust point.

As noted in Reference 2, the points on the compression line have a very clear definition between clicking and not clicking, while on those points occurring during combustion and expansion, there is a range of pressures which will give a varying frequency of clicks, ranging from full frequency down to no clicks. This was due to uneven firing, uneven rates of burning, &c., as manifested in



Reference 3 (BACA 396), due to small irregularities in injection advance angle from cycle to cycle. In this reference, the authors stated that oscilloscope readings showed a variation of  $\pm 2$  degrees in this angle.

It was regarded as most accurate for a man card, such as was being used, to record the pressure at that point at which the clicks had been reduced to approximately one half their original frequency. This is the method used by the N.A.C.A. laboratory in using balanced diaphragm types of indicators, (Reference 4).

The errors assumed to occur were the result of vibrations picked up through several months use of the indicator. They are: timing, plus or minus one degree; pressures, plus or minus five lbs. per sq. in. The gages, of the Bourdon tube type, were carefully made test gages. A calibration of these gave no appreciable error in the two higher pressure gages, and an error within the limits of experimental and plotting errors to the low pressure gage. Since the comparison of the cards and offset diagrams was entirely on a qualitative basis, any calibration errors were of negligible effect so long as they were constant.

In arriving at the limits of accuracy in this investigation the authors have purposely chosen quite large tolerances for the variables under their control, conforming



to do this rather than to lead their readers to excuse "point" accuracy and perhaps come to erroneous conclusions.

The speed of the machine was measured by a recently overhauled and calibrated tachometer, and checked at frequent intervals by a revolution counter. Speeds showed that the actual speed of the engine was being maintained within 1% R.R. of the nominal speed. An error of 10 revolutions in 870 gives a maximum speed error of 1.2%.

The brake load was maintained within  $\frac{1}{10}$  lb. at low loads (25 lbs.) and within  $\frac{1}{4}$  lb. at the higher loads of about 40 lbs. From this the brake tolerance was taken as  $\frac{1}{25}$ , or 2%.

The amount of fuel used per run was 100 cc. This was measured by means of a sight gauge alongside a standard which had a length of 10 inches. The level of the fuel in the sight gauge could be read to within  $\frac{1}{10}$  in., giving a maximum possible error of  $1/10 \times 1/10 \times 100 = .5$  cc. The percentage error would be .5%.

The time error should be negligible.

From these individual errors the following limits of accuracy were imposed upon the brake-horsepower and the fuel rates.



$$B.B.P. = \frac{R.P.S. \times \text{brake load}}{\pi \text{ constant}}$$

$$\text{Brake R.P. error} = \frac{1.0150 \pm 1.00}{\pi \text{ constant}} = \pm .7\%$$

$$\text{Fuel Rate} = \frac{\text{lbs. fuel}}{0.007 \text{ hrs.}}$$

$$\text{Fuel Rate error} = \frac{1.0050}{1 - .05} = 1.057 \text{ or } \pm 2.7\% \text{ max.}$$

By using the tolerance found above the authors felt that all their data would fall within these limits.

that you should go to the

biggest city in the state.

It's called "Anchorage".

The name means "the place where the sea meets the land".

There are many big cities in Alaska, but Anchorage is the largest, and it's also the capital of the state. It's located on the coast of the Gulf of Alaska, about 150 miles from the Arctic Ocean.

### TEST RESULTS AND DISCUSSION

Effect of Varying Orifice Diameter. In the following series of runs, all conditions were maintained constant except for the injection nozzle, and, in the runs indicated, the timing. In all runs, the #1, or original pre-combustion chamber was used, and for purposes of comparison of pressure-time cards, a uniform brake load of 31.6 R.H.P. was maintained. The original nozzle, having a .020" orifice was taken as standard. Its offset card is shown on Plate IX, and its brake economy is shown as a full line in all economy curves.

The first nozzle tested had a .010" diameter orifice.

The effect of this nozzle on brake economy is shown by curve 1, Plate VI. The effect on combustion is shown in offset card #1-1, Plate X.

From a study of the latter, in comparison with the standard card, the following was noted: (a) the beginning of the slow pressure rise, or ignition period, was advanced slightly, and the rate of pressure rise during the ignition period was increased; (b) the beginning of the period of rapid pressure rise, or inflammation period, was advanced by a crank angle of two degrees (.000417 sec.) and the rate of pressure rise during inflation was reduced; (c) the full indicator card of this run, Plate V,



shows that burning extends well through the expansion stroke, giving a very heavy pressure and high temperature at exhaust valve opening. This was also observed in the unusually high exhaust temperature as measured by pyrometer, and by visual observation of flame passing through the exhaust valve.

In the authors' opinion, the advance of the injection and the increase in the rate of burning was due to two causes. The principal cause being a purely mechanical one, brought about by the higher pressure in the injection system at closure of injection valve. This furnished a higher initial pressure in the system before the start of the next stroke, and so reduced the injection lag by reducing the amount of compression of air, and extension of pipe lines before the injection valve was lifted. The secondary cause was the more rapid heating of the fuel particles as they entered the precombustion chamber due to the finer subdivision. This finer subdivision, which was produced by the larger pressure built up in the injection system, offered a much larger total surface to the vaporisation and subsequent ignition.

In the inflammation period, the advance in timing noted was due probably to the mechanical advances mentioned above. The decreased slope of the pressure line (at 1/4



however, to (a) a slower burning because of unburned mixture, and (b) the slower rate of emission of the fuel. In this engine, the diameter of the nozzle jet was insufficient to provide combustion, and the type of the pre-combustion chamber was not conducive to turbulence. The result is that there was a very rich, slow burning mixture in the upper half of the chamber, surrounding the nozzle, and a very lean mixture in the lower end surrounding the passage to the cylinder. The flame, therefore, resolves itself into a very thin top, and gradually increasing thickness as it reaches the bottom. As has been stated, there was evidence that burning continued after exhaust. (Plates XII and XIII also substantiate this.) Mr. F. T. Jordan suggested that this was due to the distribution of fuel in the pre-combustion chamber; conditions were such, with the over-rich mixture at the top of the chamber, and the necessary combining air outside the chamber, that a considerable portion of the fuel would never come into contact with sufficient air to form a combustible mixture.

In the light of these results, it was to be expected that the thermal efficiency would suffer, as the combustion was taking place through an ineffective portion of the cycle. (Reference 5). That was the case as



shown by the comparison of the brake economy curves with that of the standard conditions.

In Plate XIV is shown a run on the same nozzle with full injection advance. An attempt was made to advance the injection until no flame appeared in the exhaust. This could not be done even with full advance. The card shows that combustion began about ten degrees before top dead center, but the amount of pressure and temperature did not differ appreciably from that obtained with normal injection advance. This indicates that combustion lasted more than 350 crank degrees, (and since injection possibly lasted that long). The economy was very poor, being only slightly better than that obtained from the same nozzle with normal advance.

The next nozzle tried was one having an orifice diameter of .330". All other conditions were maintained the same. The effect of this nozzle on combustion is shown in Plate XI.

A comparison of this offset card with the standard shows that the timing and rate of pressure rise during the ignition period were the same as that of the standard. However, the commencement of the inflammation period was delayed considerably, and the rate of pressure rise during the inflammation period was increased. The amount of the delay was 11.2 crank degrees, or .00275 seconds.

with their names down but the same name will make  
the other players not go back  
to their seats and give a chance to all persons at  
the game, even though one continues winning and others make  
one effort to win. With an added emphasis on equality  
and team work now, no one can claim victory. Thus  
makes you have more fun and less stress. This  
methodology is good for the students to learn and  
work hard and get involved with the full participation and  
enthusiasm and interest and a different kind of  
teamwork and the same kind of motivation goes  
with it. And that makes it more interesting to teach  
such a difficult subject and makes your class less  
boring. I am going to try this method and  
see how we could use the same system from our  
classroom and see how it would work. As a teacher  
you should always try to find new ways to teach and  
make your class more interesting and less  
boring.

This delay may be almost entirely charged up to increased injection lag due to the large area of the orifice bleeding over the injection passage before the end of the discharge stroke. This is shown in Reference 6. In this investigation, conducted at Langley Field, the authors show pressures in the injection system during the pump discharge for nozzles of .020, and .030", respectively, for the same pump speeds. In general, the curves show the pressures with the .020 nozzle to be less than half those with the .030" nozzle, and the final pressure in their particular case to be about 300 lbs. per sq. in. for the latter case, as against 100 lbs. per sq. in. for the .020" nozzle. No means were available of measuring the fuel pressures built up in the engine under investigation, but it may be assumed for comparison, that the pressures in the two cases were in approximately the same proportions.

The more rapid rate of pressure rise during inflammation was explained by the more rapid rate of injection, the fact that there was more fuel in the chamber before inflammation took place, due to the larger particles, and the more favorable distribution of the spray. In this case, the heavy, solid spray is sent down toward the cylinder passage in such manner that the ignition of the finely divided "border" spray near the nozzle will blow

En el año 1870 se creó la Comisión de Hacienda, que convocó a los principales ministros del país para tratar la situación económica. La Comisión recomendó la creación de un Banco Central que tuviera autoridad sobre las demás entidades financieras y que estableciera una tasa de interés que sirviera de base para las demás. El Congreso aprobó la ley en 1875, estableciendo el Banco Central como la institución encargada de emitir moneda y controlar el sistema monetario. Sin embargo, el Banco Central no comenzó a funcionar hasta 1884, cuando el presidente Joaquín V. González nombró a su primer director, el ingeniero Juan José Arribalzaga. El Banco Central comenzó a emitir moneda en 1885, estableciendo una tasa de interés fija de 5% anual. La tasa de interés se mantuvo constante durante todo el siglo XX, excepto en períodos de inflación o deflación severa.

En 1925, el presidente Arturo Prat estableció la Comisión Monetaria, que recomendó la creación de un Banco Central que tuviera autoridad sobre las demás entidades financieras y que estableciera una tasa de interés que sirviera de base para las demás. El Congreso aprobó la ley en 1926, estableciendo el Banco Central como la institución encargada de emitir moneda y controlar el sistema monetario. Sin embargo, el Banco Central no comenzó a funcionar hasta 1930, cuando el presidente Arturo Prat nombró a su primer director, el ingeniero Juan José Arribalzaga. El Banco Central comenzó a emitir moneda en 1931, estableciendo una tasa de interés fija de 5% anual. La tasa de interés se mantuvo constante durante todo el siglo XX, excepto en períodos de inflación o deflación severa.

the overrich mixture out into the cylinder to unite with the air there to form a combustible mixture. The economy obtained from this nozzle, while much better than that obtained from the .010" nozzle, was not so good as that obtained from the standard nozzle.

The same nozzle was then tested with the injection more advanced. The amount of advance was not definitely known, but by an arrangement of pins and holes, the position was fixed, and was repeated for all other runs of "advanced injection".

This advance (Plate VII) brought the beginning of the inflammation period up to three degrees before top dead center,--an advance of about 72 degrees (.0016 sec.) over the same nozzle with normal advance, or about 9 degrees (.0100 sec.) advance over the standard conditions. Rate of pressure rise during inflation was judged to be about the same, considering its rise above the non-firing compression-expansion curve. The maximum pressure in this case was increased to 750 pounds per square inch as compared with 680 for the normal advance. As would be expected from the offset card, the same economy was improved (Curve I, Plate VI) over that obtained with the normal injection, but was slightly poorer than the original economy. Exhaust temperatures were not sensibly different from the same nozzle at normal advances.



The sound of the engine was noticeably louder and rougher than for any other condition tested. A maximum brake horsepower of 45.7 (BHP 77.6; IHP 111.6) was reached, but at this load there was considerable knocking. This was partially due to the advance of timing with increased load, an inherent mechanical feature of the fuel pump, which will be discussed later.

Acting on the theory, derived from the first two trials, that the fine atomisation of the .015" nozzle, to give rapidity of ignition, combined with an increase of area to give more speedy injection were desirable, the operators next installed a nozzle having five .018" diameter nozzles. This gave an increase of area of twenty-five percent over the original nozzle. The pressure-time curve is shown on Plate XIII. Inasmuch as a few trial runs with normal injection showed late inflammation, and comparatively poor results, the recorded runs were made with advanced injection.

The increased lag in this case over the standard condition is charged, probably, to distribution lag. The penetration of the fine spray was estimated to be about one-half the length of the precombustion chamber. This would give a condition of approximately one-fourth of the total combustion volume being filled with an overrich, and therefore slow burning mixture. The reason



of combustible mixture would be a surface on the cylinder side of the spray cone, and, therefore, instead of the combustion pressure tending to force the burning mass into the cylinder, it tended to force it back against the nozzle. The effect of this was regarded as important. Mr. R. D. Hill (Reference 11) states that investigation at the Mill Diesel Engine Company showed the pressure differential between the precombustion chamber and cylinder ranges from 100 to 150 pounds per square inch. This was found by taking direct pressure cards on the precombustion chamber and cylinder. This pressure, if generated behind the mass of the fuel has an excellent effect on distribution.

With advanced injection, economy slightly poorer than the standard conditions were obtained. The engine seemed to be constant and smooth in its operation. A maximum load of 48.2 brake horsepower (BHP 46.9; IHP 135.8) was obtained by dropping the injection advance back to the normal position. This retarding was necessary to counteract the inherent injection advance with increase of load, as mentioned above.

On all offset card and economy curve plates has been shown a full size sketch of orifice size and arrangement in the precombustion chamber and spray button used for that run.

and the 1990s and 2000s. While a new African continent is being born, the old one is still there, continuing to exert its influence over the new. This is particularly true in the case of South Africa, which has continued to play a significant role in the continent's politics and economy. The country's political system is based on a multi-party system, with the African National Congress (ANC) being the largest party. The ANC has been in power since 1994, and has overseen significant economic growth and development in the country. However, despite this progress, South Africa continues to face challenges, including poverty, inequality, and unemployment. The government has implemented various policies to address these issues, but progress has been slow and uneven. In addition, the country's political system is often criticized for being too centralised and too dominated by the ANC.

#### *Conclusion*

The continent of Africa is undergoing significant changes, both internally and externally. The continent's political systems are changing, with many countries transitioning from one-party states to multi-party systems. The continent's economies are also changing, with some countries experiencing rapid growth and others facing challenges such as poverty and inequality. The continent's international relations are also changing, with the rise of China and India as major global powers. The continent's cultural and social norms are also changing, with increasing urbanisation and globalisation leading to new ways of life. The continent's environment is also changing, with climate change and environmental degradation becoming major concerns. Overall, the continent of Africa is a complex and dynamic place, with many challenges and opportunities ahead. The continent's future will depend on how it chooses to respond to these challenges, and how it can work together to build a better future for all.

EFFECT OF VARIOUS PRECOMBUSTION CHAMBERS ON COMBUSTION

The various precombustion chambers used in this investigation are shown in Plate II. A brief description of them follows:

#1. This was the precombustion chamber previously installed on the engine, and will taken as representing the standard for comparison. The orifice between the antechamber and cylinder was  $5/16"$  in diameter, and was sharp-edged.

#2. This antechamber had three orifices, arranged symmetrically about the center, as shown in Plate XVI. The diameter of each orifice was  $1/4"$ . Orifices were sharp-edged.

#3. This precombustion chamber had a single  $9/16"$  diameter orifice, as shown in Plate XV. The orifice was sharp-edged.

#2a. This was the #2 chamber with the exception that the orifice had been flared out on both sides to form a rounded entrance orifice.

#4. This chamber had an orifice of  $7/8"$  diameter. This practically eliminated the effect of the precombustion chamber.

The performance with #1 precombustion chamber has been discussed in the previous section as it was used in all the tests with varying outer nozzle diameter. In



In the following investigation, the .000" diameter nozzle was used throughout, and the load and speed were made constant as in the previous section.

The pressure-time card for a pre-combustion chamber is shown in Plate VI.

The effect on combustion of this pre-combustion chamber was to increase slightly the rate of pressure rise during the ignition period, and to delay the beginning of inflammation 1.0 degree (.0005 sec.). The engine operation was very rough, and its load carrying capacity was very erratic. Great difficulty was experienced in keeping the load and speed constant. The only explanation suggested by the authors for this was that the arrangement of the antechamber orifices with metal in the center, roads up the center of the oil spray, and disrupts the heavy oil jet, which by optimum conditions would carry into the cylinder. The economy varied slightly from that under the original conditions.

The next pre-combustion chamber tested (3) had a single  $\frac{9}{16}$ " orifice. The effect card of this chamber is shown in Plate V. In this test, the beginning of inflammation was about the same time as in the original conditions, but the rate of pressure rise during inflammation was much more rapid. Operation of the engine seemed very smooth and regular. The economy showed an improvement

and the same could be true of other species. In addition, we have seen that the mean age of the youngest birds was 1.6 years, which is only half the mean age of the oldest birds. Thus, the distribution of ages shows an interesting trend.

The data also indicate that the mean age of the oldest birds is 4.0 years, which is considerably older than the mean age of the youngest birds.

Age measurements were made at various times during the year and it is difficult to determine exactly how old each bird is. However, it is possible to estimate the approximate age of each bird by comparing its size with the size of other birds of known ages. For example, the size of a 1-year-old bird is approximately 10 cm long, while a 2-year-old bird is approximately 12 cm long, and so on. This method of estimating age is based on the assumption that all birds of the same age are of similar size. This is not always true, however, because some birds may grow faster than others, and some may stop growing earlier than others. Nevertheless, this method provides a rough estimate of the age of each bird.

The data also show that the mean age of the oldest birds is 4.0 years, which is considerably older than the mean age of the youngest birds. Thus, the distribution of ages shows an interesting trend. The data also indicate that the mean age of the oldest birds is 4.0 years, which is considerably older than the mean age of the youngest birds. Thus, the distribution of ages shows an interesting trend.

over any previous run, especially on lighter loads. The authors hesitate to advance any theory as to the performance of this chamber. It was felt that there must be an optimum size for this orifice, but the number of variables entering into this problem made it difficult to determine. The size of this orifice is a function of cylinder and antechamber dimensions; the relative volumes of each; the percentage of combustion occurring in the antechamber, and hence the volume of gas to be passed through it; the pressure differential available through the orifice; and many others. This orifice size was chosen, because it was found at the B.I.C.A. Laboratories at Langley Field, (Reference 3) that for their test engine with identical cylinder dimensions, and gas distribution of combustion gases between cylinder and antechamber, that this was the best size. The form of the combustion chamber, however, was radically different.

In order to study the effect, if any, of the degradation of heat into kinetic energy in the antechamber velocities through the antechamber orifice, an attempt was made to reduce this velocity by increasing the coefficient of discharge. This was accomplished by flaring out both sides of the 1/2 combustion chamber (#3) and converting it from a sharp-edged orifice to a convergent-divergent nozzle. Slight differences could be noted in

other names or initials, or other markings, are very  
difficult to discern. The bodies of deceased animals will  
decay, but they are not so apt to do so as the carcasses.  
Animals and their products will not have much time to grow  
old before they are eaten, but still we can see evidence of age  
in the animals. An animal may be quite old, and the skin  
may indicate the following characteristics: the hide may  
not be sufficiently tanned, so it will become soft, greenish  
brown, or yellow. The connective tissue may become  
more elastic, so that the animal may be more supple than usual.  
The hair will become sparse, and the coat may appear  
dusty-colored. These are the chief signs of old age, but  
there are other signs which are not so apparent. The animal  
will be poor off vital fluid, and will have less force.  
The heart will be small, and the lungs will be thin,  
and the eyes will shrink and appear pale. As  
the body of an aged animal will have the following  
peculiarities: emaciation, and general debility; the  
skin will be dry, and the mucous membranes will be  
reduced to a minimum. The fat will be reduced. The glands will  
be small, and the organs will be weak. The animal will  
have a slow metabolism, and will be unable to digest its  
food. The animal will be unable to excrete its waste products.

the pressure-time card (Plate XVII). The rate of pressure rise during combustion was reduced. The economy, however, on light loads was further improved. It is believed that there was an appreciable reduction in friction horsepower due to this change, because there was an improvement in economy which was more marked at the lower loads.

Pre-combustion chamber #4 caused a greatly increased ignition lag. For comparable results, data was recorded with the timing in the advanced position. The offset card is shown in Plate XVIII. The size of this orifice was such as to practically eliminate the pre-combustion feature of the engine, and to convert this space into cylinder volume. This would reduce the velocity of the jet of gas and fuel emerging from the antechamber, and, while the loss to kinetic energy would be less, the loss due to lower velocity and accompanying turbulence in distributing the charge through the cylinder combustion space was greater. That this was the case was indicated by the increase in lag (increase in distribution and after penetration lag) and the poorer economy resulting.

Time was lacking to pursue the subject of pre-combustion chambers further, but it was felt that the optimum size lies in the neighborhood of 9/16" diameter, rounded entrance orifice.

1990-1991. Also, many new institutions and  
universities have implemented similar study programs,  
and many "multicultural" students make up a significant  
percentage of our upper year courses. As a result  
of these academic changes, there is now considerable interest in  
the nature and development of multiculturalism in  
higher education. In addition, the recent  
and growing interest in diversity management  
in the workplace also has had a significant influence  
on the study of multiculturalism in higher education.  
The term "multicultural" refers to the study of  
and appreciation of the diversity of cultures and  
ways of life within a society. It is a broad and  
inclusive concept that encompasses a variety of  
issues related to the study of culture, ethnicity,  
and race. Multiculturalism is concerned with  
the study of the relationships between different  
cultures and how they interact with each other.  
It is also concerned with the study of the  
ways in which different cultures are represented  
and how they are perceived by others.  
Multiculturalism is a relatively new field of  
study, and it is still developing. There is  
a great deal of research being done in this  
area, and it is hoped that this will lead to  
a better understanding of the complex  
relationships between different cultures.  
Multiculturalism is an important field of  
study, and it is hoped that it will lead to  
a better understanding of the complex  
relationships between different cultures.

Some difference in performance may have been accounted for in the slight change in design of pre-combustion chambers Nos. 2, 3, and 4. These were furnished by the Hill Diesel Engine Company, and were made to a modified design. It had been thought that the original pre-combustion chambers on their engines of the type of PL, were operating at too cool a temperature due to the complete water jacketing surrounding them in the cylinder head. To increase this temperature, an attempt was made to reduce the heat dissipated to the cooling water by increasing the depth of the undercut on the sides. This can be seen in the photograph (Plate II). Temper colors on the periphery of the latter types of chambers indicated that their operating temperatures were higher than the originals.

In general, it was found that economy was rather insensitive to wide changes in pre-combustion chamber design, although other operating characteristics, such as, noise, and evenness of operation were more sensitive.

**Effect of Load on Ignition Advance Angle.** Plate XIX shows the marked effect of load on commencement of inflammation. In general, the lighter the load, the greater the delay in ignition. This was found to be due to the design of the fuel metering system. The method of metering is to very the opening of a nozzle cavity



needle valve on the suction side of the fuel pump. When the engine is throttled down, a greater quantity of oil is allowed to leak back before the commencement of delivery, and hence delivery occurs later in the pump stroke. Since the cam action is constant, this causes later injection in the cylinder. To offset this effect, all pressure-time curves recorded were taken at uniform loading.

Plates XX and XXI show the pressure-volume relationships plotted on logarithmic coordinates.

Plate XI is the diagram for the standard .337" bore engine. The slope of the compression line is about 1.35, while the slope of the expansion line varies from 1.17 in the early part of the expansion after reaching the top of the curve to 1.8 during the last half.

There is no fixed value in the opinion of the authors that may be assigned to the amount of the expansion line that could be taken as typical of a good engine. Since the rate of injection and rate of burning vary, it is possible that a number of values may be acceptable. However, it is quite evident that in a Diesel engine it is preferable that the expansion exceed unity, as a value of less than unity would indicate that the rate of generating the heat of combustion exceeds the net loss and the work done, thus causing the temperature to rise in the cylinder as it approaches the end of the stroke.



Plate XXI, the diagram for the .910" nozzle, shows this effect. In this case the slope of the saturation line is .9 and, as indicated in the temperature-entropy diagram, (Plate XIII), the temperature is highest at about the point of exhaust.

Plate XII shows a more inefficient cycle than could probably be obtained with an air engine having a cut-off near the end of the stroke. It has taken very little advantage of the expansion properties of the working fluid.

The authors, however, do not feel that too critical an analysis should be made of this type of exponential curve. The slight inaccuracies inevitable in taking indicator cards will give erratic and misleading information if this analysis is carried to extremes.

Plate XIII shows the temperature-entropy relationships for the cycle. The curve in blue shows this relationship for the standard .910 in. orifice while the curve in red is for the .910" orifice.

In constructing these curves, it was necessary to arrive at some figure for the size of gases in the cylinder.

In arriving at the value of .0044 lbs. of fluid in the cylinder, the authors resorted themselves of three methods for finding the mass, viz.:

many citizens have not yet learned all this again.

But when we did, we did it in the spirit of freedom and with maximum enjoyment of our freedom, as we do at

Race Day. That's the attitude that makes us happy.

Now, the lesson of

many more difficult experiences was to learn the value

and meaning of the individual family in

affectionate and kind relations and care. The

lesson of the more difficult experiences was to understand

the value of family life in its personal and

spiritual as well as its material aspects. Likewise the

value of personal independence. And all these

values were learned from the same source, the same

experience of education at Harvard and the University

of Cambridge, and from the same people.

And this taught us many other things, not least

that it is important to know ourselves and our surroundings

well enough to be able to live in them.

It taught us to know ourselves and our environment well

enough to

know the other person, or persons, we are connected to.

It taught us to understand people, and to understand just as

honestly about people as we can.

1.  $m_{air} = \frac{M_{air} V_{air}}{P_{air} \cdot \text{temp.} \times \text{gas constant}}$
2.  $m_{fuel} = M_{fuel}/C_F \times \text{air fuel ratio}$
3.  $m_{mix} = \frac{\text{mass of air of compression stroke} + m_{air}}{\text{gas const.} \times \text{temp. mix.}}$

By taking the average of the values found by these three methods a value of  $m_{mix}$  was obtained.

For purposes of computation it is not important that the exact value of the mass within the cylinder be determined, since an approximate value will give the general shape and show the tendencies with much accuracy. The only difference would be one of position and it was believed that the value used given this position with sufficient fidelity for this purpose. As an additional check, the value of the maximum temperature found by computation using the formula illustrated by Professor H. A. Verneuil in his paper "The Prediction of Maximum Cylinder Temperature attained in Actual Internal Combustion Engines" checked quite closely with the values shown.

The temperature-entropy diagram sheets were constructed by Professor H. A. Verneuil of The Pennsylvania State College and are corrected for the effect of the variation of electric heat with temperature.

Plate XIII shows that in the early part of the compression stroke both curves approach an adiabatic compression, and both show loss of entropy due to cool-



ing towards the end of the conversion. From this point on, the curves are quite dissimilar. That of the .310 is, nearly reaches its maximum temperature at an earlier percentage than the .310 but remains up at a point considerably earlier in the stroke. It has a temperature & greater efficiency when it is making progress at the temperature rise.

The .310 is, no doubt, on the contrary, in doing its major work over a lower average temperature and thus more economically discharging its heat at about 18% less temperature.

In the case of the pure parameter curve, it is seen from data sheet #5 that the initial temperature has first reached at a point about 30°-35° past the dead center.

This could easily be checked by the tangent method of Dr. F. R. Soddy (Reference 1). While the complete analysis of this card was not regarded as consistent enough to be published, it is believed sufficient that the point of maximum temperature as indicated by this method occurred at completion of 12% of stroke, or about 37° after the dead center. This checks the temperature-entropy diagram very closely.

Another interesting correlation lies in the fact that the slope of the log  $\tau$  - log V plot of this card

there's been some significant research recently with

the field of Total Reinforcement Schedules and you  
would like to know what makes the different schedules and  
what makes the new ones and also the past research  
is somewhat over 10 years old and we would like  
you to review some of the more recent developments.

All right so probably you are probably interested in  
the most up-to-date things and I have made  
and can see them in your new electronic version

of the document so I will just say that the  
summarized version has been put together by myself  
and there's lots of other folks in the Internet that have

written documents on reinforcement schedules etc.  
and either my summaries summarize it all and the  
info changes and goes back and forth and I think  
most people who are interested in reinforcement schedules  
will find something useful probably the best one will probably be  
the one written by Dr. B.F. Skinner himself and it's quite  
well known and widely used. It's available online at  
cognition.yale.edu. An additional document with some  
good information is the one written by Dr. B.F. Skinner  
himself which is available at [www.yale.edu/cognition/](http://www.yale.edu/cognition/) and I think

(Plate XII) at this point of maximum curvature is unity, which shows the tangent analysis of the point  $\theta = \frac{\pi}{2}$ .



CONCLUSION

Spray nozzle orifice size has an appreciable effect upon the combustion in a Diesel engine cylinder. The optimum size of injection nozzle orifice in the engine under consideration was .020 in. Smaller orifices decreased the rate of burning causing combustion to last up to the point of exhaust valve opening; larger orifices increased the injection lag and hence caused a delay in the start of combustion but a more rapid burning ensued.

Precombustion chamber orifice size had small effect upon the economy especially at lower loads near the rated horsepower. Several characteristics, such as quietness, smoothness of operation, regularity of cycles, which could not be evaluated in laboratory tests, but which are important to the builder and operator were affected. In general, the best results were obtained with the  $\frac{9}{16}^*$  rounded orifice nozzle chamber.



ACKNOWLEDGEMENTS

The authors wish to acknowledge the kindness and assistance of the Mechanical Engineering Department of The Pennsylvania State College in the preparation of this thesis.

They are particularly indebted to Professor H. A. Everett and associate professor J. B. Stewart for their constant interest and constructive criticism.

They also wish to express their thanks of the assistance rendered by assistant professor W. R. Grace and the Hill Steel Engine Company in the furnishing and drilling of the combustion chamber and cylinder; and of the valuable comments and suggestions of Mr. W. F. Josselin, Mr. H. D. Still, Dr. P. H. Schmidler and Assistant Professor Salomon J. De Janasz.

and the other members of their families and  
friends contributed a total of \$10,000.00. This contribution has  
enabled us to conduct many more services than we could  
otherwise have done. The small  
amount of additional contributions will  
enable us to continue our services to the  
poor and distressed here. We sincerely thank you all  
and the members of your church for their kind  
offer of an additional amount of money. Your  
generosity and the promptness with which you have con-  
tributed to our services amazes us and we sincerely thank  
you all for your kind offer.

BIBLIOGRAPHY

1. A High Speed Engine Pressure Indicator of the Balanced Diaphragm Type. By H. C. Uteimann and F. B. Sewall. Technical Report No. 107, National Advisory Committee for Aeronautics, 1921.
2. Indicator Cards as Criteria of Diesel Engine Performance. By D. I. Mitchell. Thesis for the Degree of Master of Science, The Pennsylvania State College, 1931.
3. Performance of a Compression-Ignition Engine With a Pre-combustion Chamber Having High-Velocity Air Flow. By J. A. Spanogle and C. W. Moore. Technical Note No. 390, National Advisory Committee for Aeronautics, 1931.
4. Basic Requirements of Fuel-Injection Systems for Quiescent Combustion Chambers. By J. A. Spanogle and E. A. Foster. Technical Note No. 382, National Advisory Committee for Aeronautics, 1929.
5. Internal Combustion Engines. By E. L. Streeter and L. C. Liggett, McGraw-Hill Book Company, 1931.



6. Penetration and Duration of Fuel Sprays from a Pump Injection System. By A. H. Rothrock and J. T. Harsh. Technical Note No. 395, National Advisory Committee for Aeronautics, 1931.
7. The Testing of High-Speed Internal Combustion Engines. By Arthur W. Judge. Chapman and Hall Ltd., London, 1924.
8. A Thermodynamic Analysis of Internal-Combustion Engine Cycles. By Goodenough and Baker. Bulletin No. 160, Engineering Experiment Station, University of Illinois.
9. The Tangent Method of Analysis for Indicator Cards of Internal Combustion Engines. By F. E. Schweitzer. Bulletin No. 39, Machine ing Experiment Station, The Pennsylvania State College.
10. Lectures delivered by Mr. W. F. Jeochim at The Pennsylvania State College on 27 April 1932.
11. Lectures delivered by Mr. E. D. Hall of the Hall Diesel Engine Company at The Pennsylvania State College on 4 May 1932.
12. The High-Speed Internal Combustion Engine. By Harry R. Ricardo, F.R.S., New York, 1931. Chapter XIII. P. Van Nostrand Company.

more than 1000 books the collection was nevertheless  
not complete. In 1978, another additional  
10,000 were given from a local business man.

Other additions to the collection continue  
uninterrupted, though much has to compete with  
other more popular subjects of interest at present.

46000 volumes within  
the collection, ranging in subject matter from  
classical and classical literature up to modern and  
modern authors, from well known names such as

Shakespeare to unknown  
writers and unknown titles.

Concerning the collection the author thought that  
it is the modern authors, however, that have  
been the most popular, with the exception of  
classical literature.

With the addition of 2000 new titles which include  
titles from the 1970's and 1980's, the collection  
now totals 46,000 volumes.

The library is open to the public during  
normal business hours, and the author would like  
to thank all those who have contributed to the  
success of the library.

The author would like to thank all  
those who have contributed to the  
success of the library.

LIST OF PLATES

- I Photograph of Mill engine showing installation of Balanced Diaphragm Indicator.
- II Photograph of Precombustion Chambers and Spray Nozzles.
- III Crank engine vs. per cent of stroke.
- IV Indicator Diagram, Standard nozzle.
- V Indicator Diagram, .010" nozzle.
- VI Economy curves.
- VII
- VIII
- IX to XVIII, Inc. Offset diagrams.
- XIX Effect of load on L.H.P.
- XX Log P vs. Log V, Normal Chro.
- XXI Log P vs. Log V, .010" nozzle.
- XXII Temperature-Entropy Diagram.
- XXIII Pressure Element, Balanced Diaphragm Indicator.
- XXIV Timer, Balanced Diaphragm Indicator.
- XXV
- XXVI Schematic Diagram of balanced Diaphragm Indicator Electric Circuit.



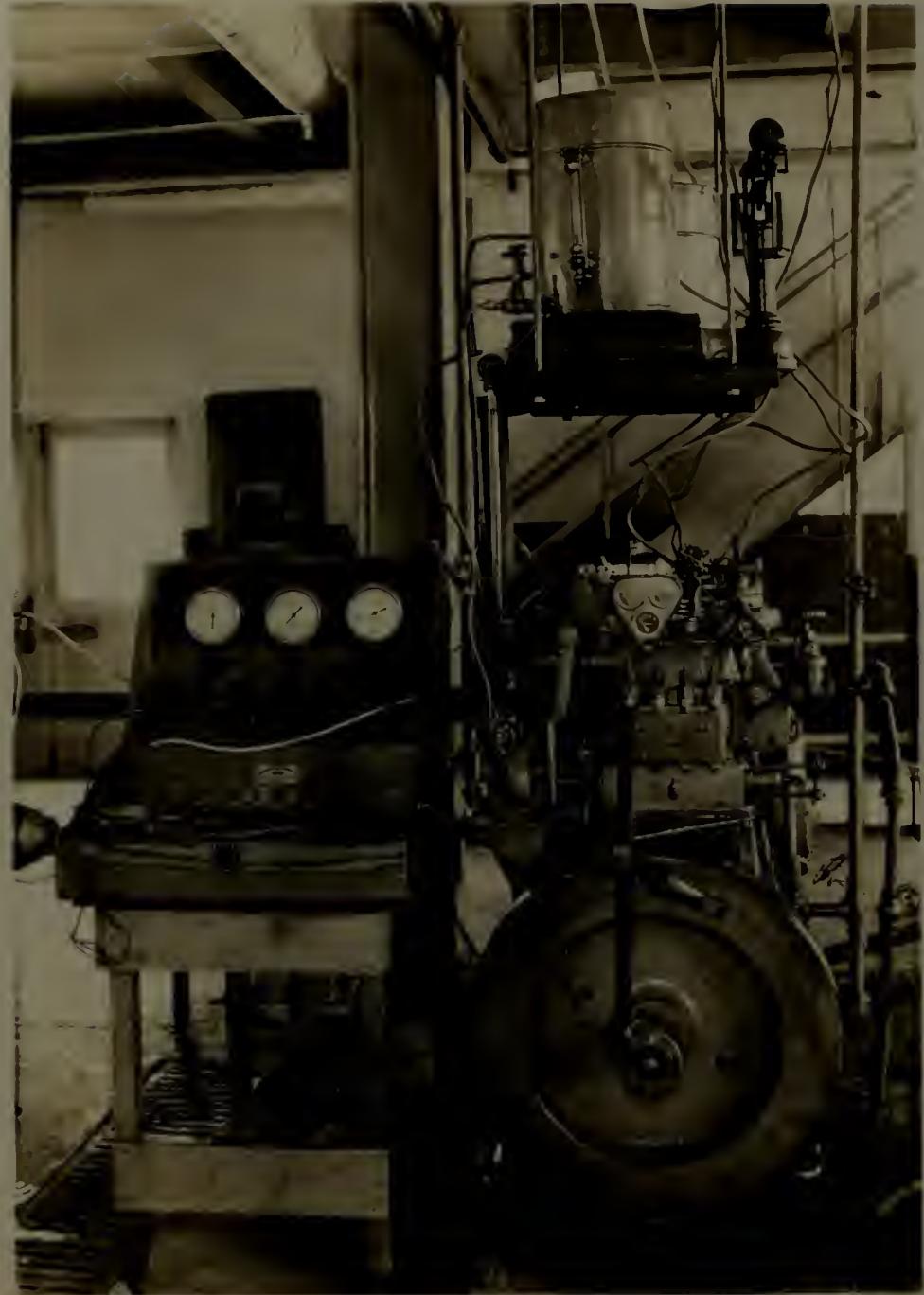
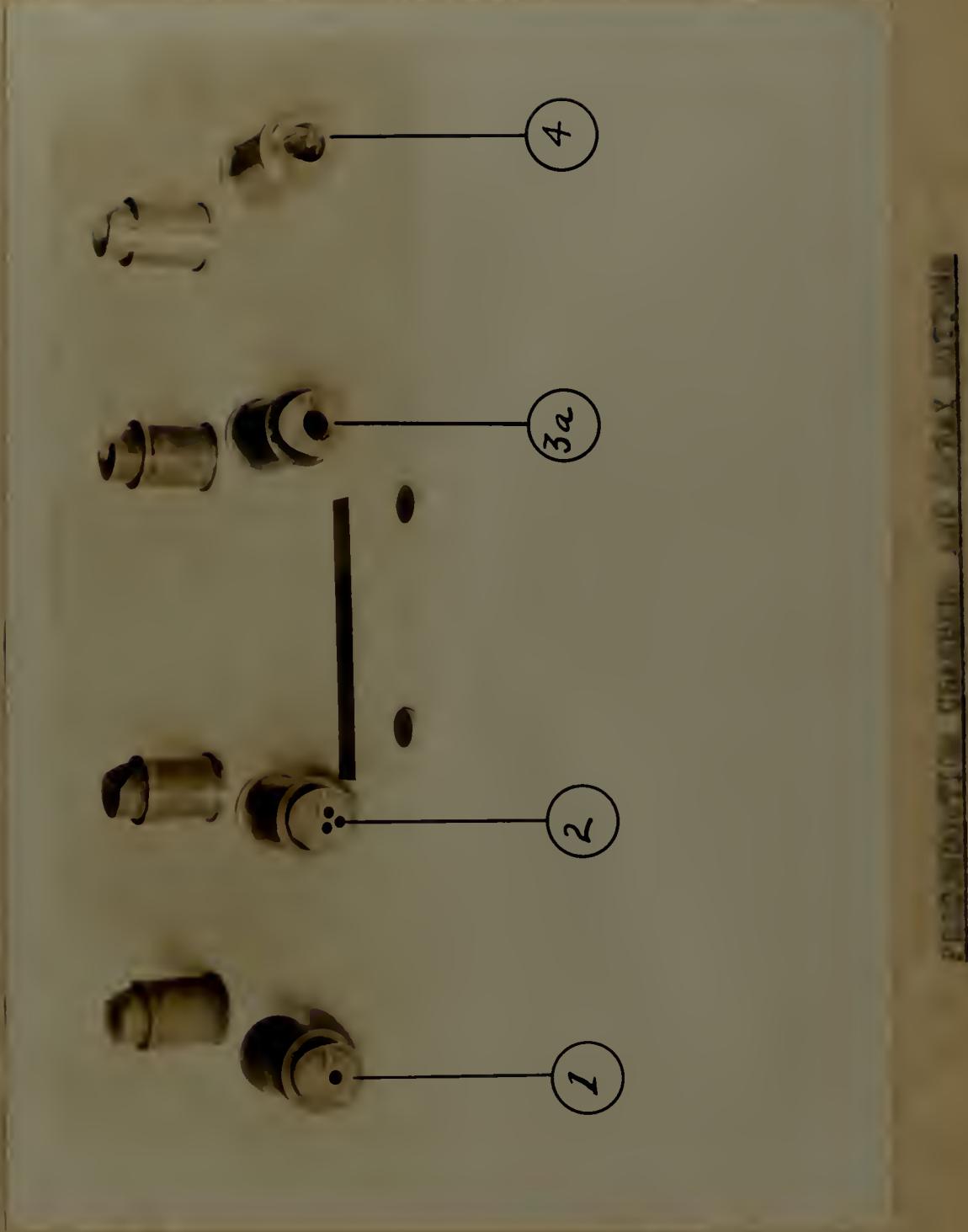
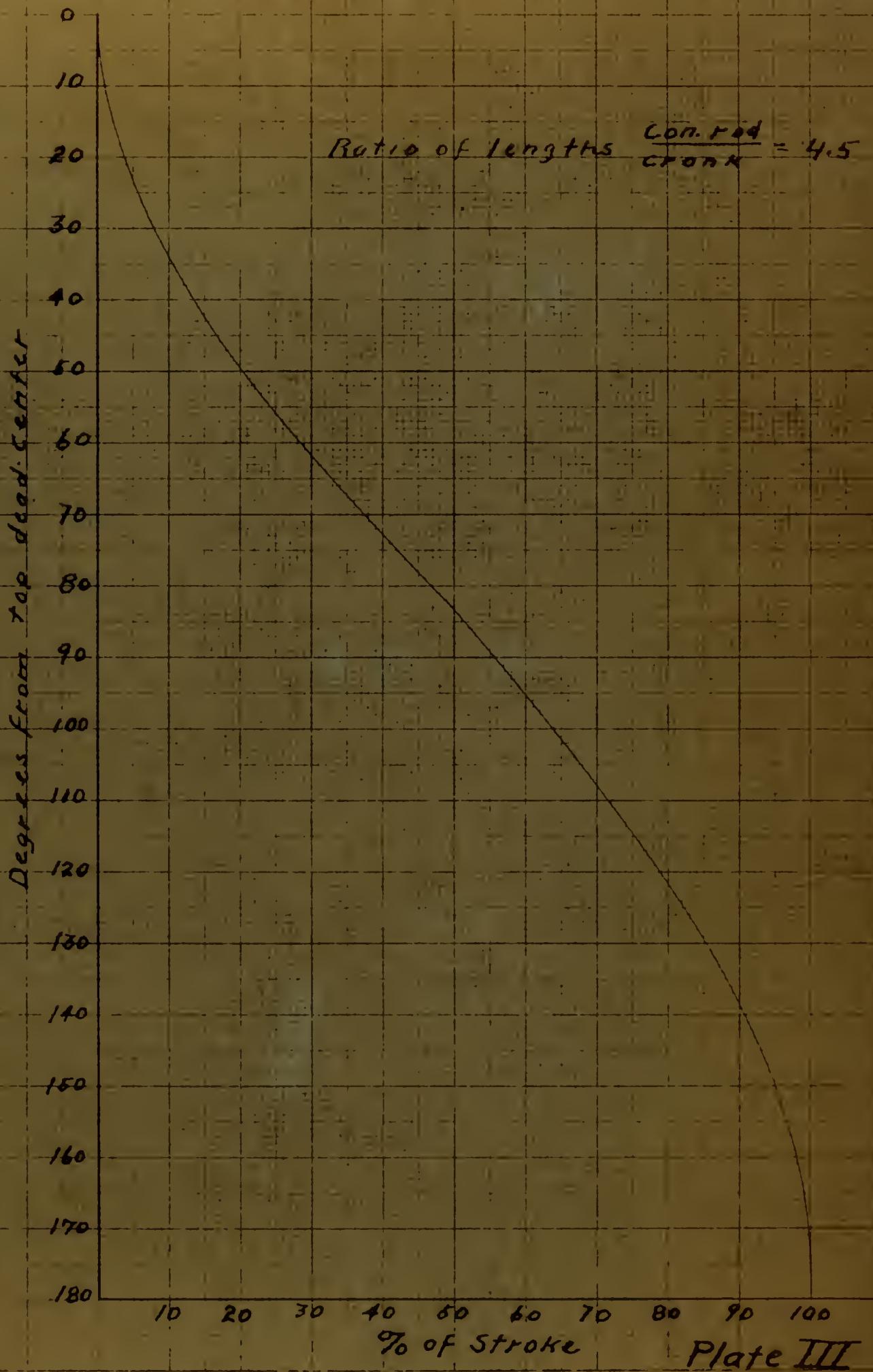


PLATE I









1. 2. 3.

4. 5. 6.

7. 8. 9.

10. 11. 12.

700

600

500

400

300

200

100

0

Card #1-4. Nozzle diameter .010"

Precombustion Chamber #1.

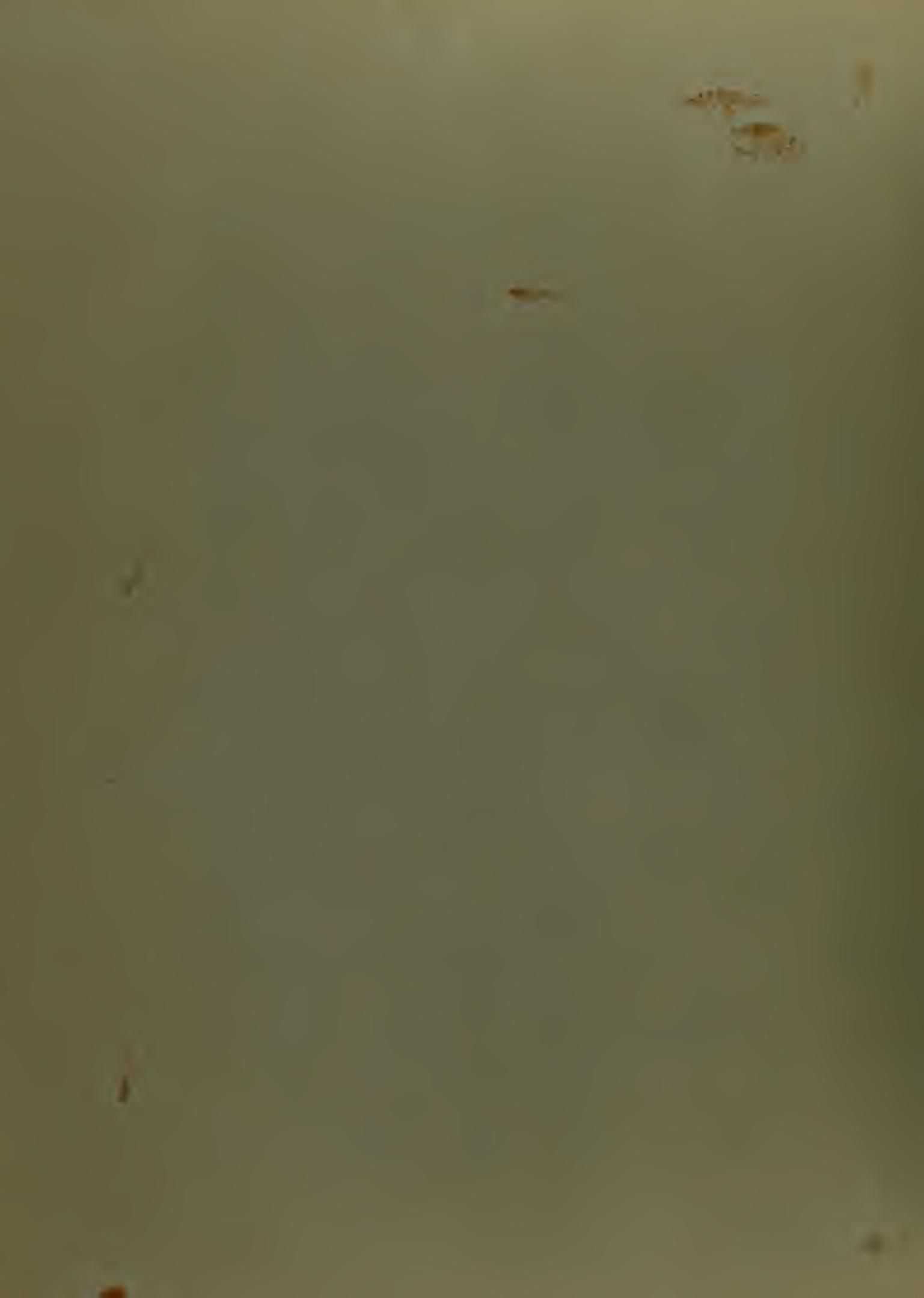
800 R.P.M. 02 B.H.P.

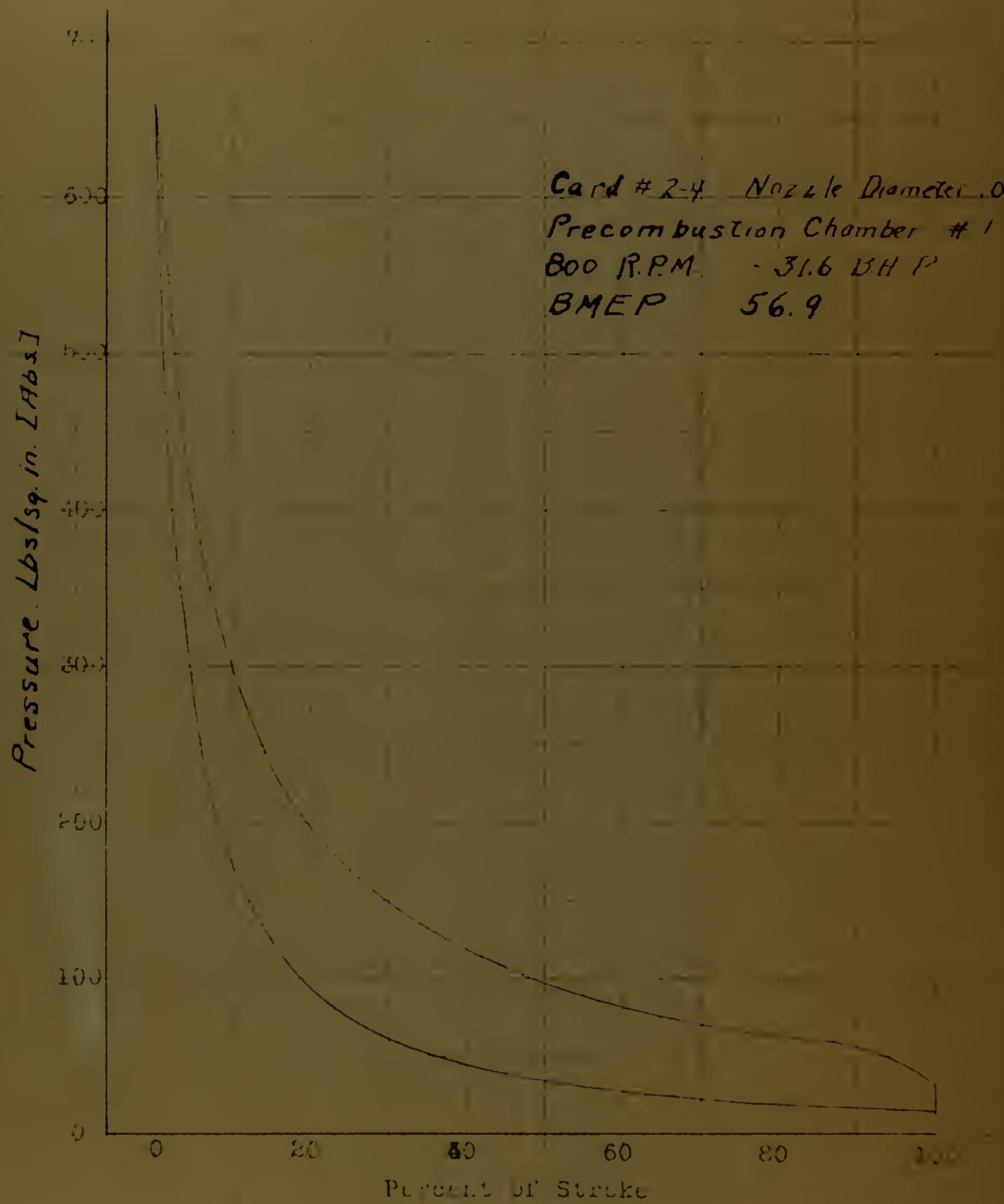
H.M.P. - 57.6.

Card I.M.H.P. - 67.3

Percent of Stroke.

PLATE IV







Curve 1.

.010" diameter nozzle, #1 Precombustion Chamber.  
Normal Advance.

Curve 2.

.050" diameter nozzle, #1 Precombustion Chamber.  
Normal Advance.

Curve 3.

.050" diameter nozzle, #1 Precombustion Chamber.  
Full Advance.

100      50      75      100  
Percent Rated Load,





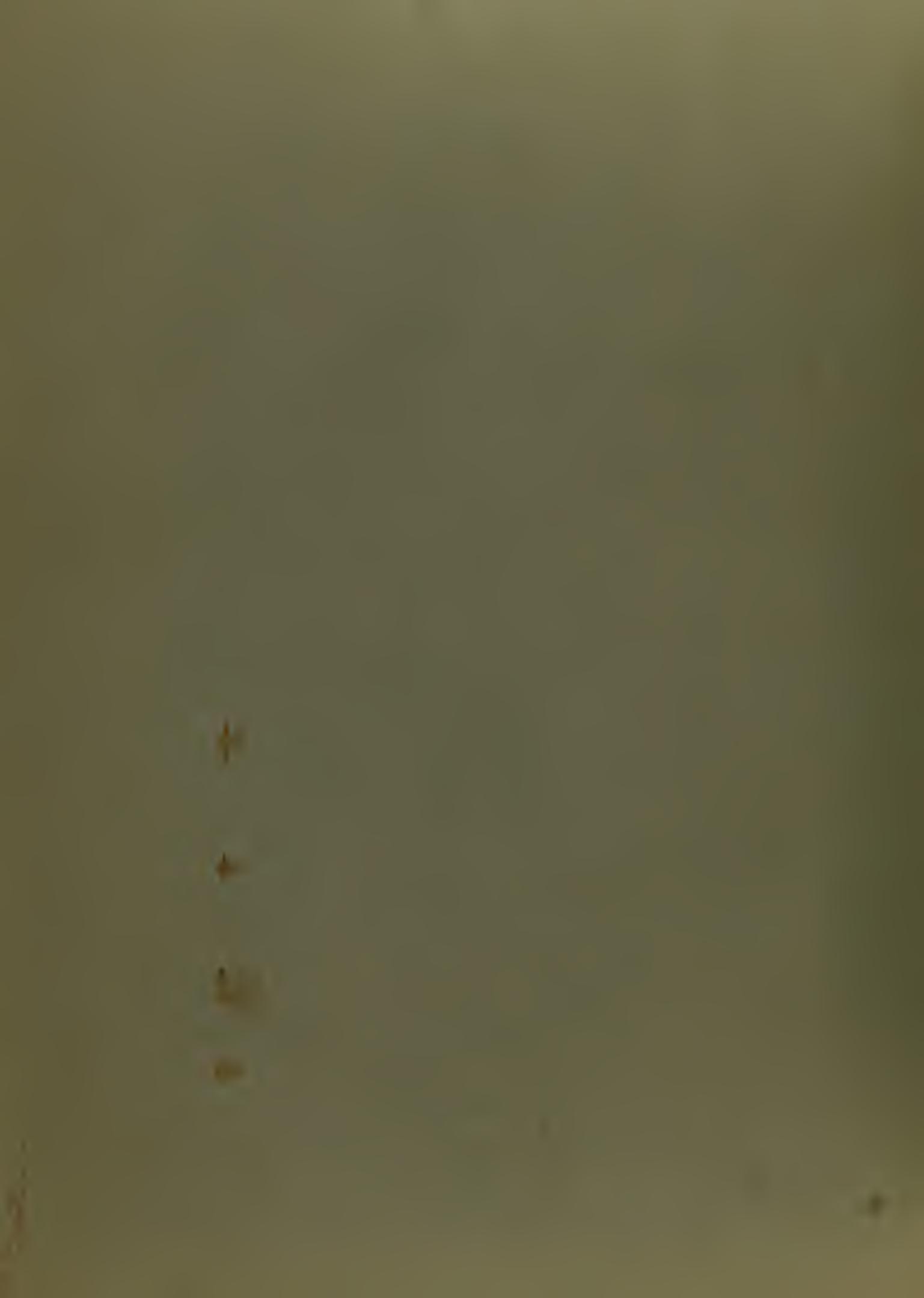


PLATE VIII

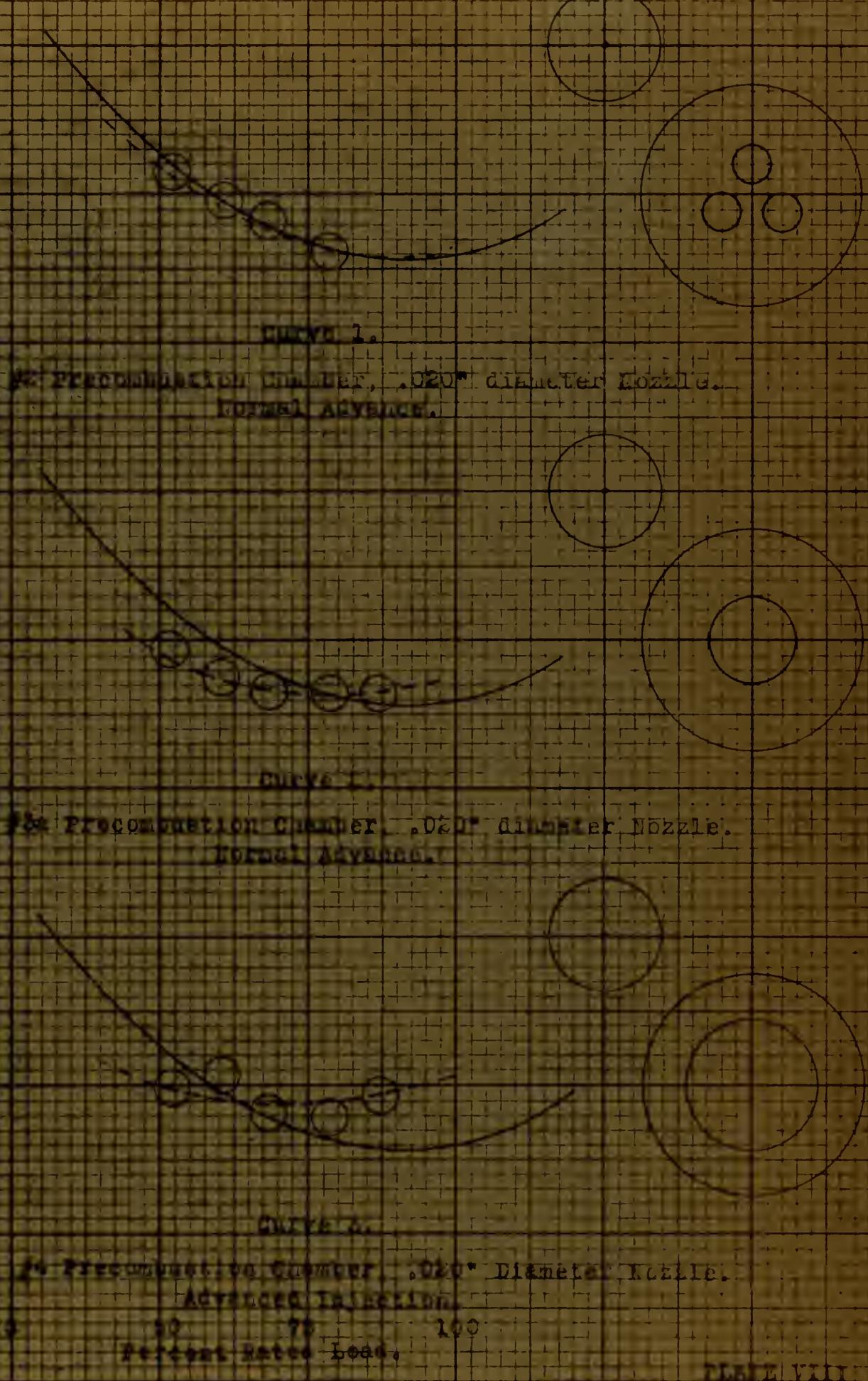
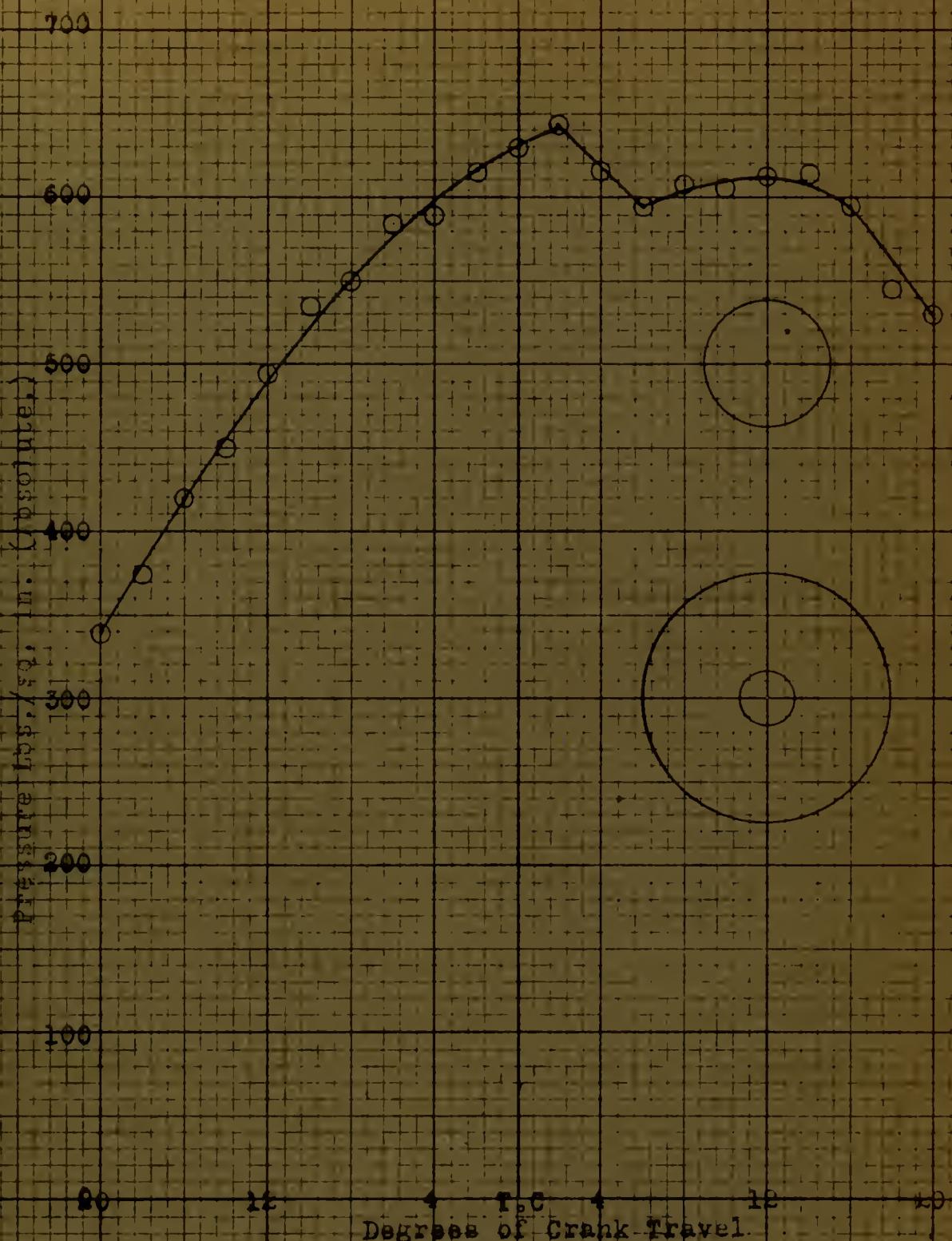


PLATE VIII





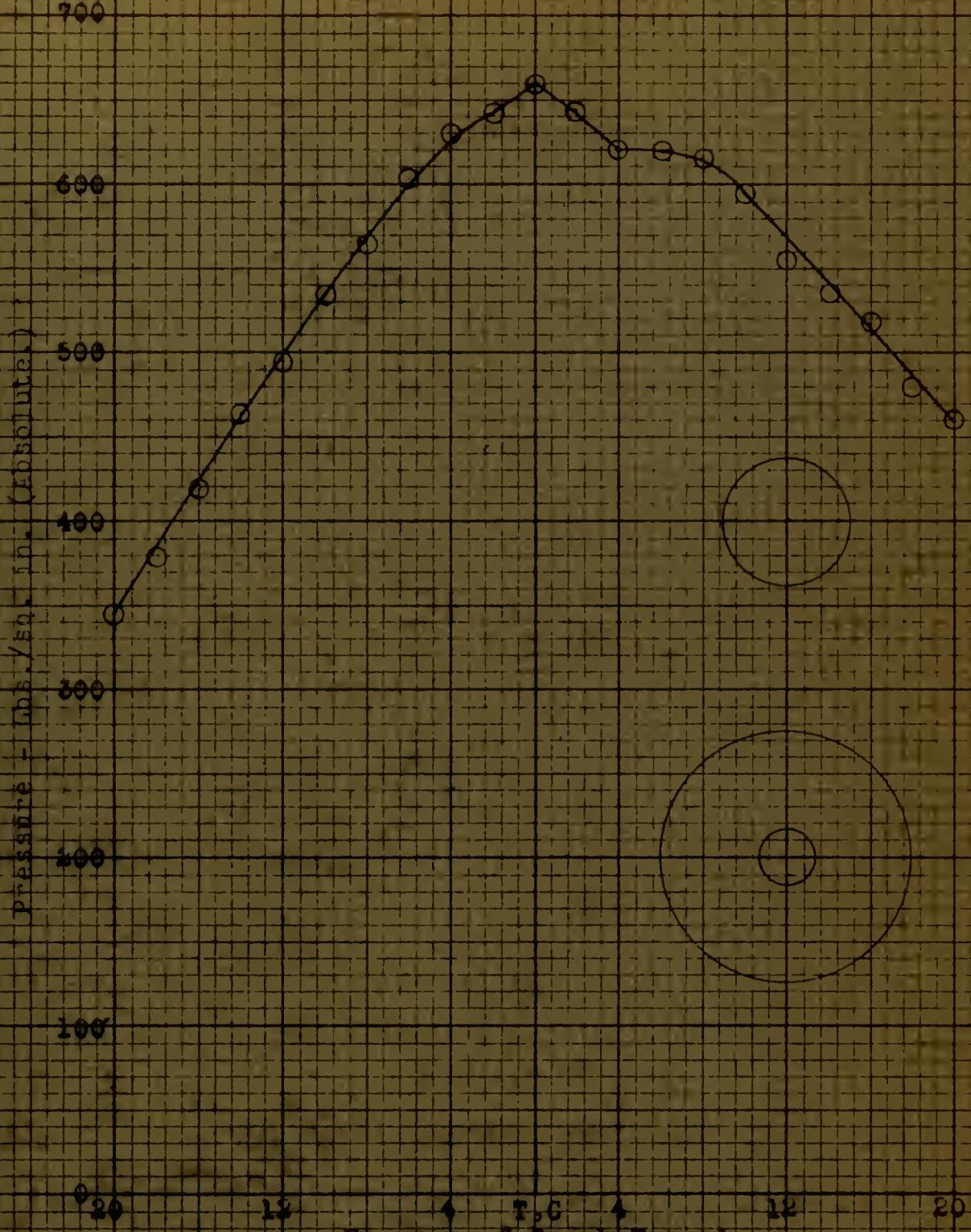
Card #1-3. Nozzle Diameter .010".  
Precombustion Chamber #1.

800 R.P.M.

32 B.H.P.

B.M.E.P. = 57.6 lbs./sq.in.  
Economy: .505 lbs. fuel/BHP/hr.

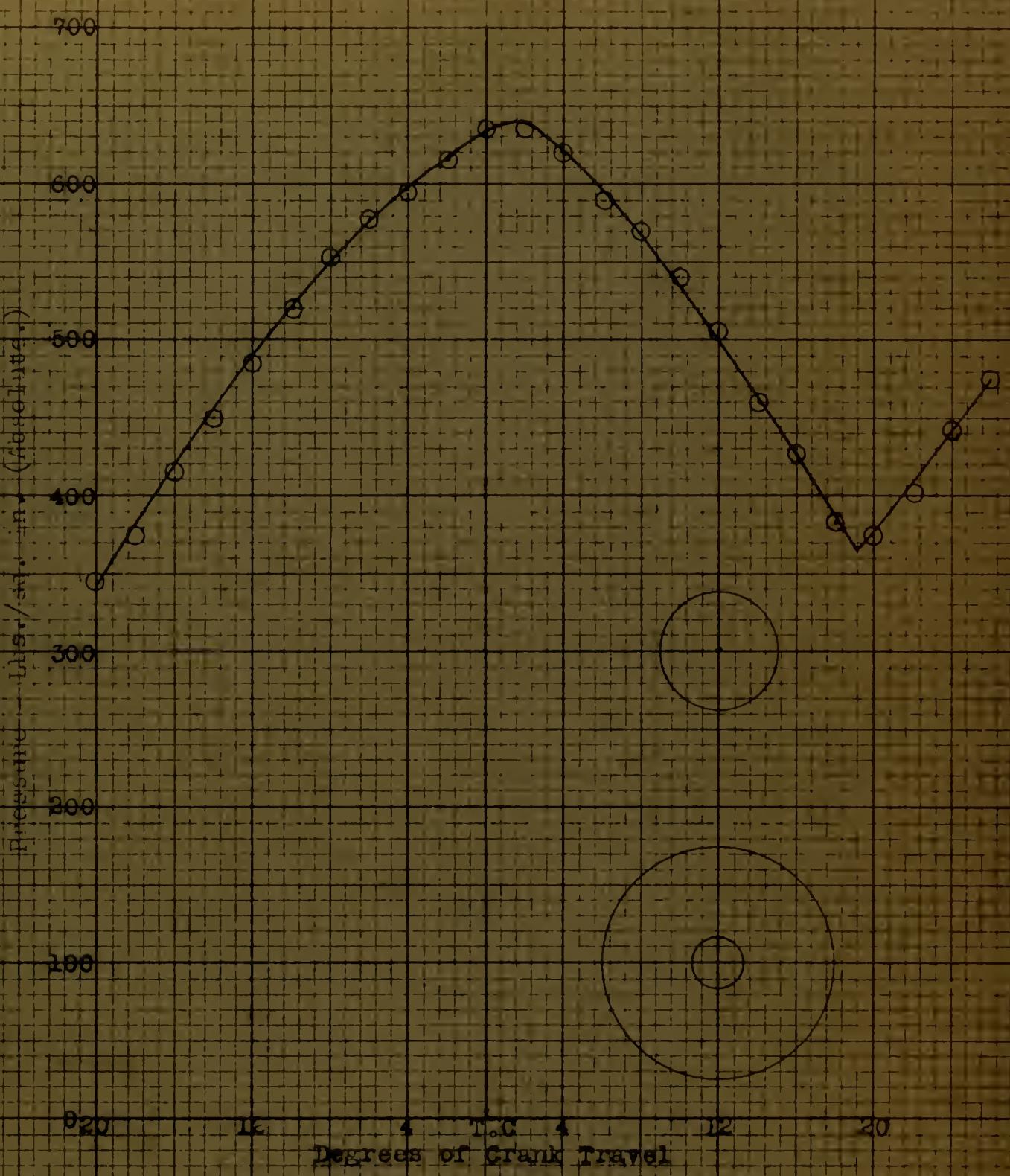




Card #2-4. Nozzle Diameter .010"  
precombustion Chamber #1.

600 R.P.M. 31.6 B.H.P. B.M.E.P. = 56.9 lbs<sub>p</sub>/sq.in.  
Economy: .800 lbs. fuel/BHP/hr.

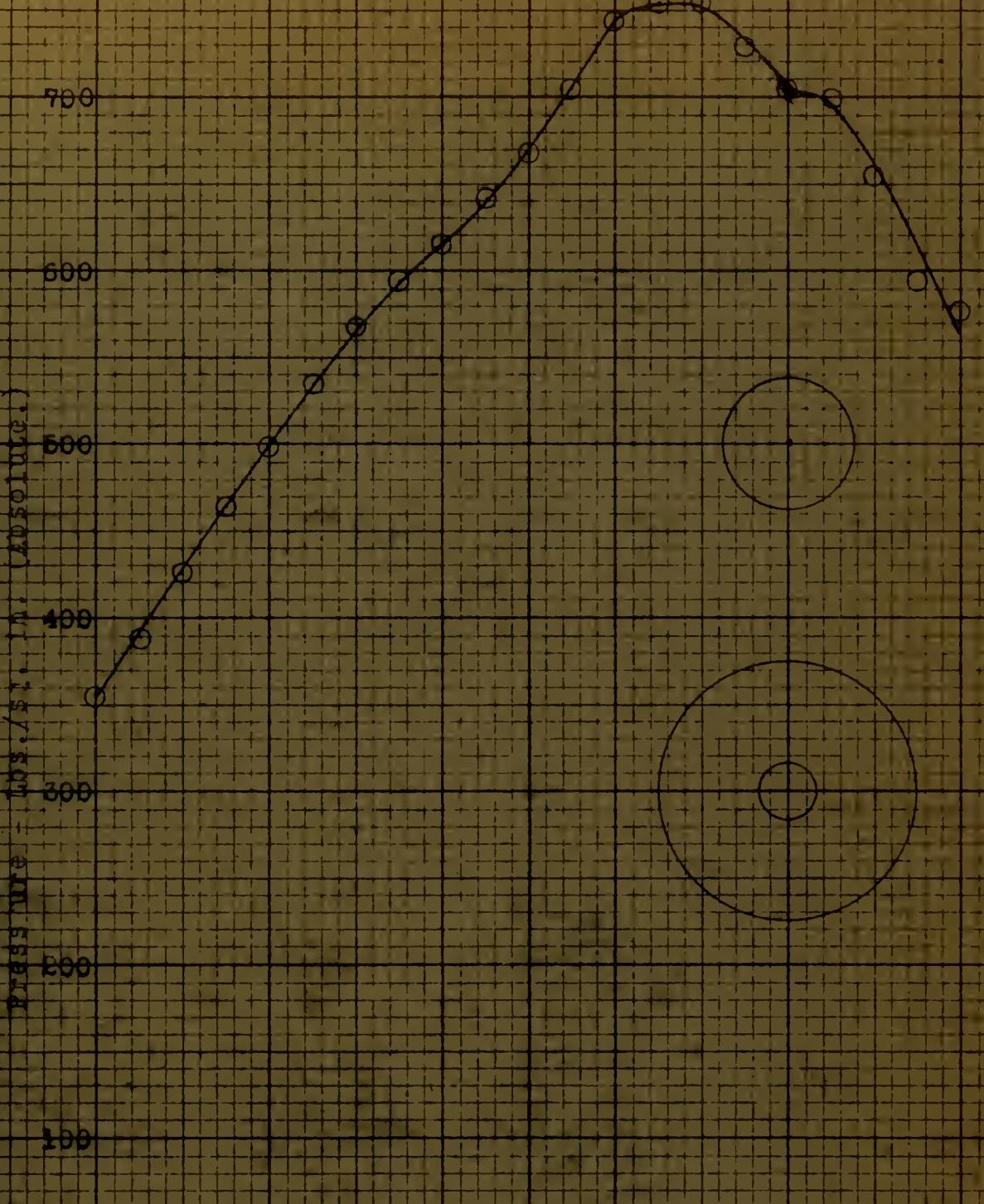




Card #3-2. Nozzle Diameter .030"  
Precombustion Chamber #1.

800 R.P.M. 31.6 R.H.P. 14.4 B.H.P. - 56.9 lbs./sq.in.  
Economy: .572 lbs. fuel/BHP/hr.  
Normal Injection Advance.





0 10 12 4 T.C. 4 12 20

Degrees of Crank Travel

Card #4-3. Nozzle Diameter .030"

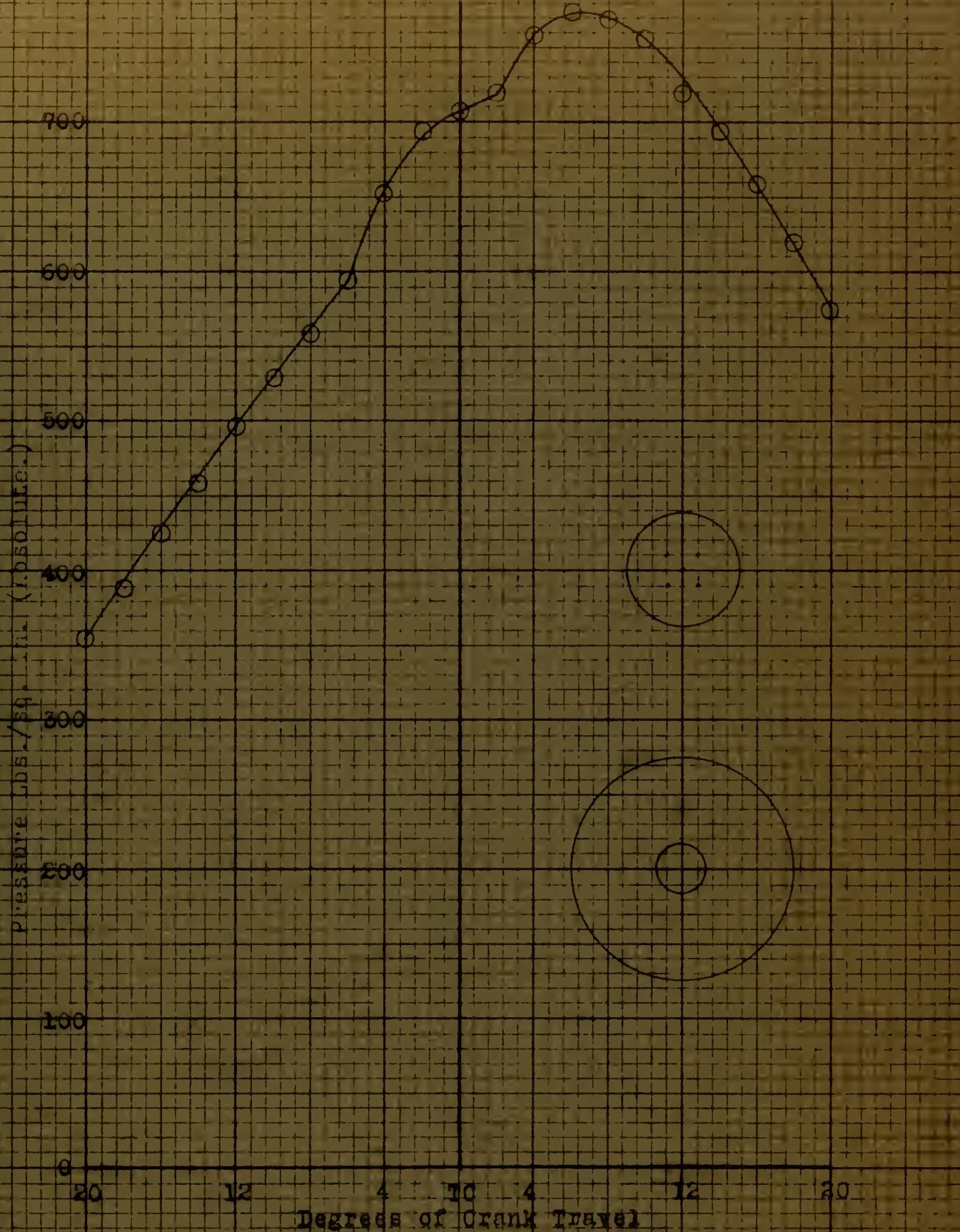
Precombustion Chamber 11.

800 R.P.M. 31.6 B.H.P. B.M.E.P. = 56.9 lbs./sq.in.

Economy: .542 lbs. fuel/lb.p/hr.

Advanced Injection.

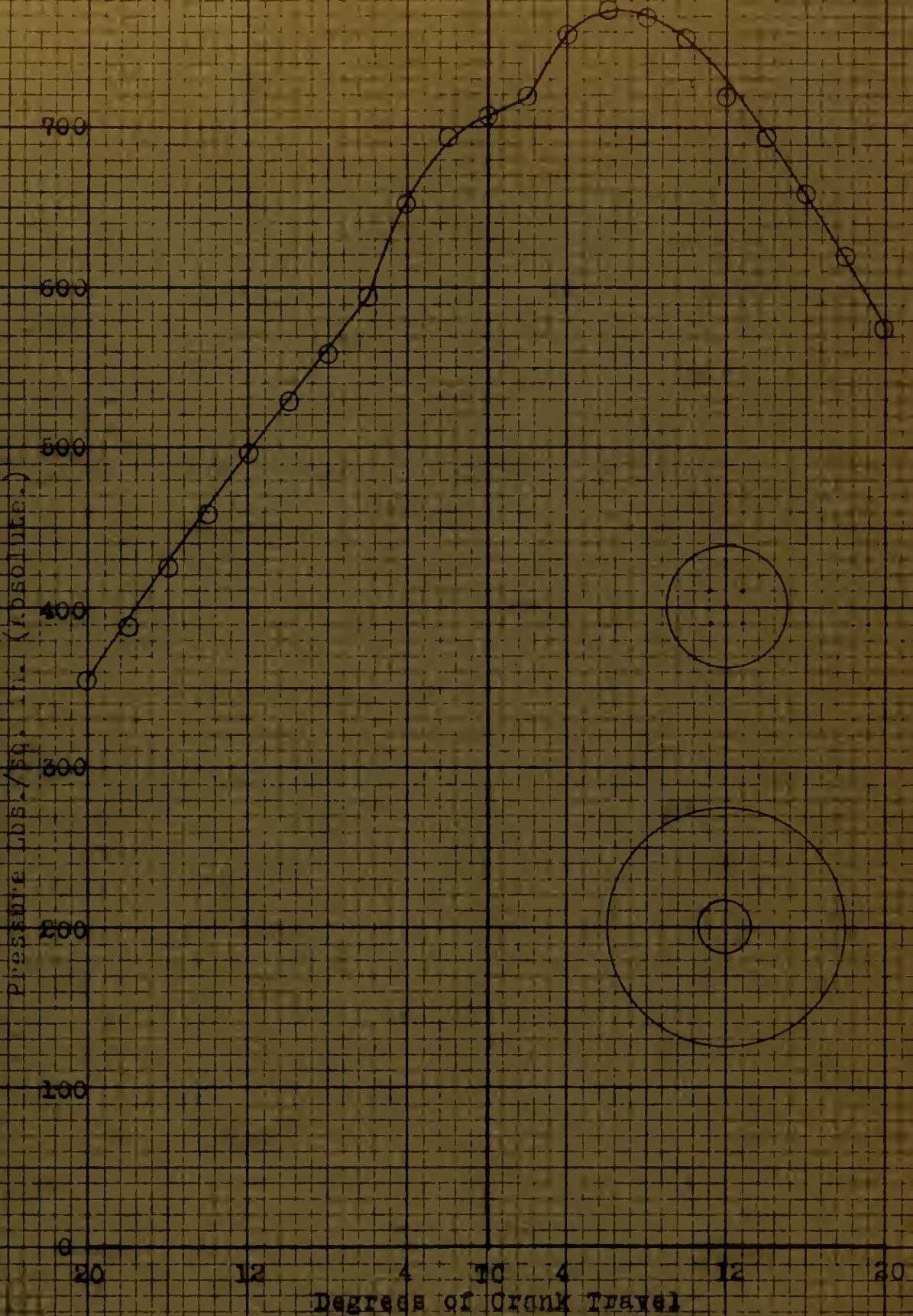




Card #3-5. Nozzle Diameter .010" - 5 Orifices.  
Precombustion Chamber #1.

800 R.P.M. 31.6 R.H.P. B.M.H.P. = 66.9 lbs./sq.in.  
Economy! 544 lbs. fuel/BHP/hr.  
Advanced injection.

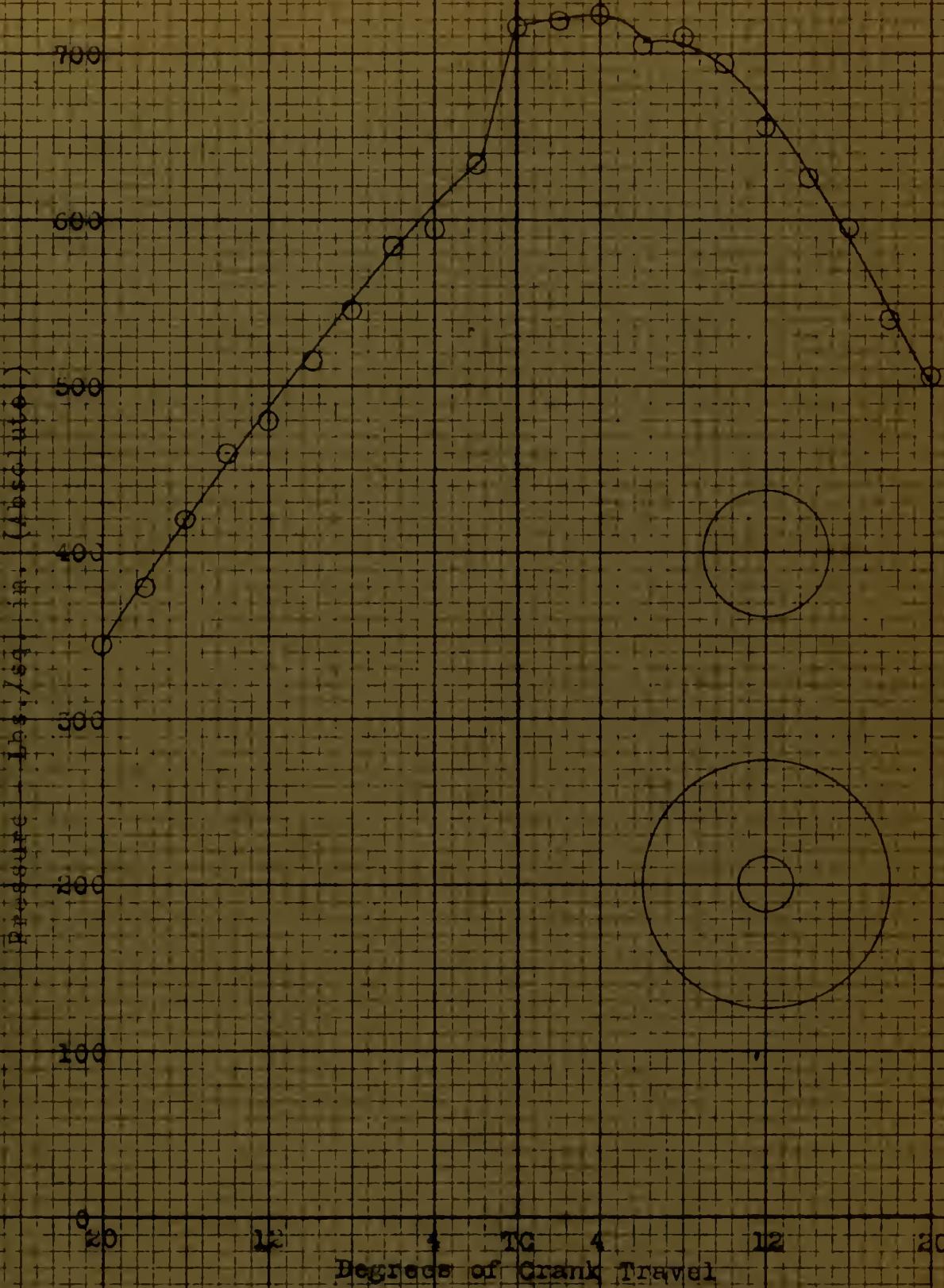




Card 43-5. Nozzle Diameter .010" - 5 Orifices.  
Precombustion Chamber #1.

800 R.P.M. 34.6 R.H.P. B.M.H.P. = 56.9 lbs./sq.in.  
Economy: 544 lbs. fuel/R.H.P./hr.  
Advanced Injection.

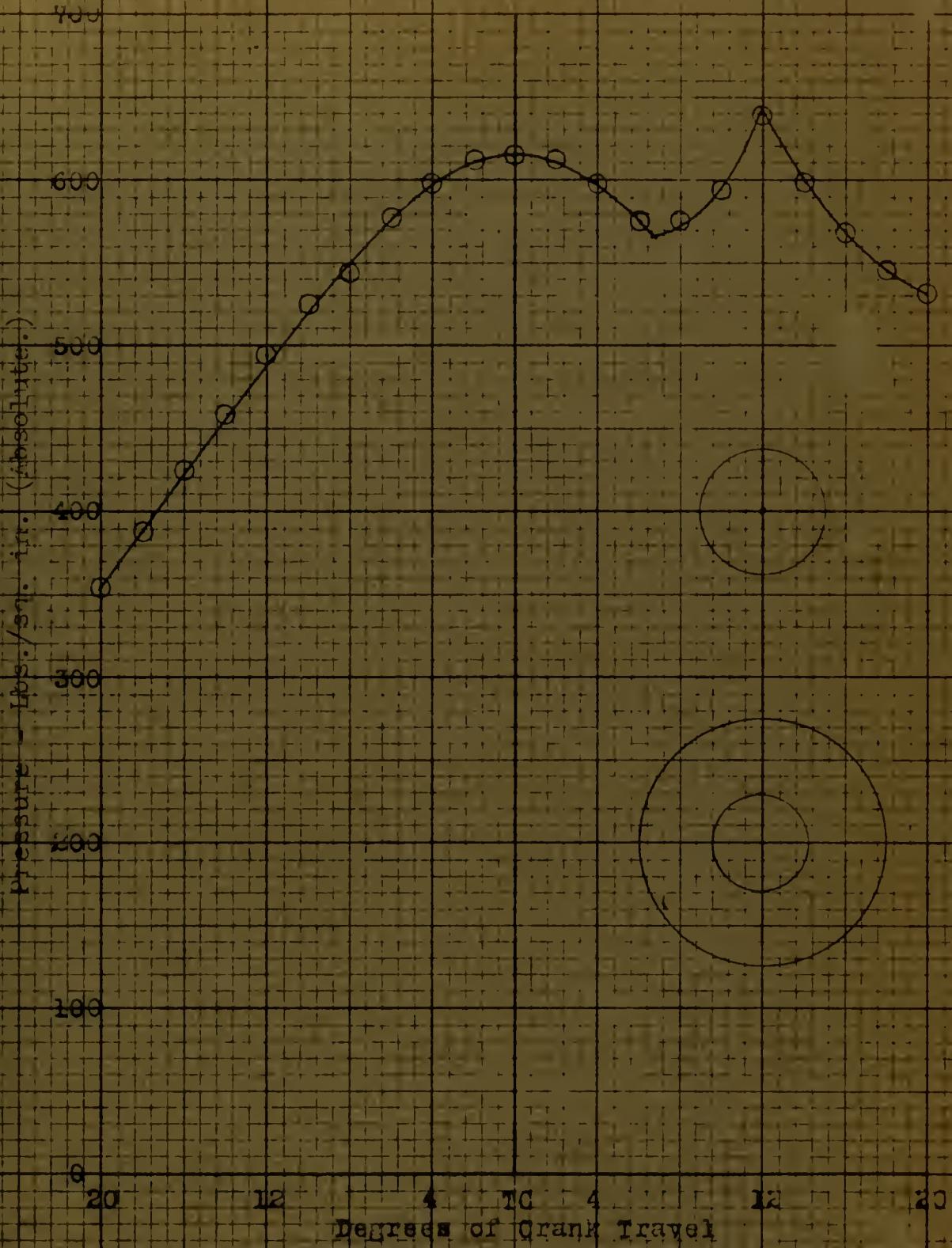




Card #5-46 Nozzle Diameter .010"  
Precombustion Chamber #1.

500 R.P.M. 31.6 B.H.P. P.M.E.P. - 56.9 lbs./sq.in.  
Economy: .306 lbs fuel/Hp/hr.  
Advanced Injection.

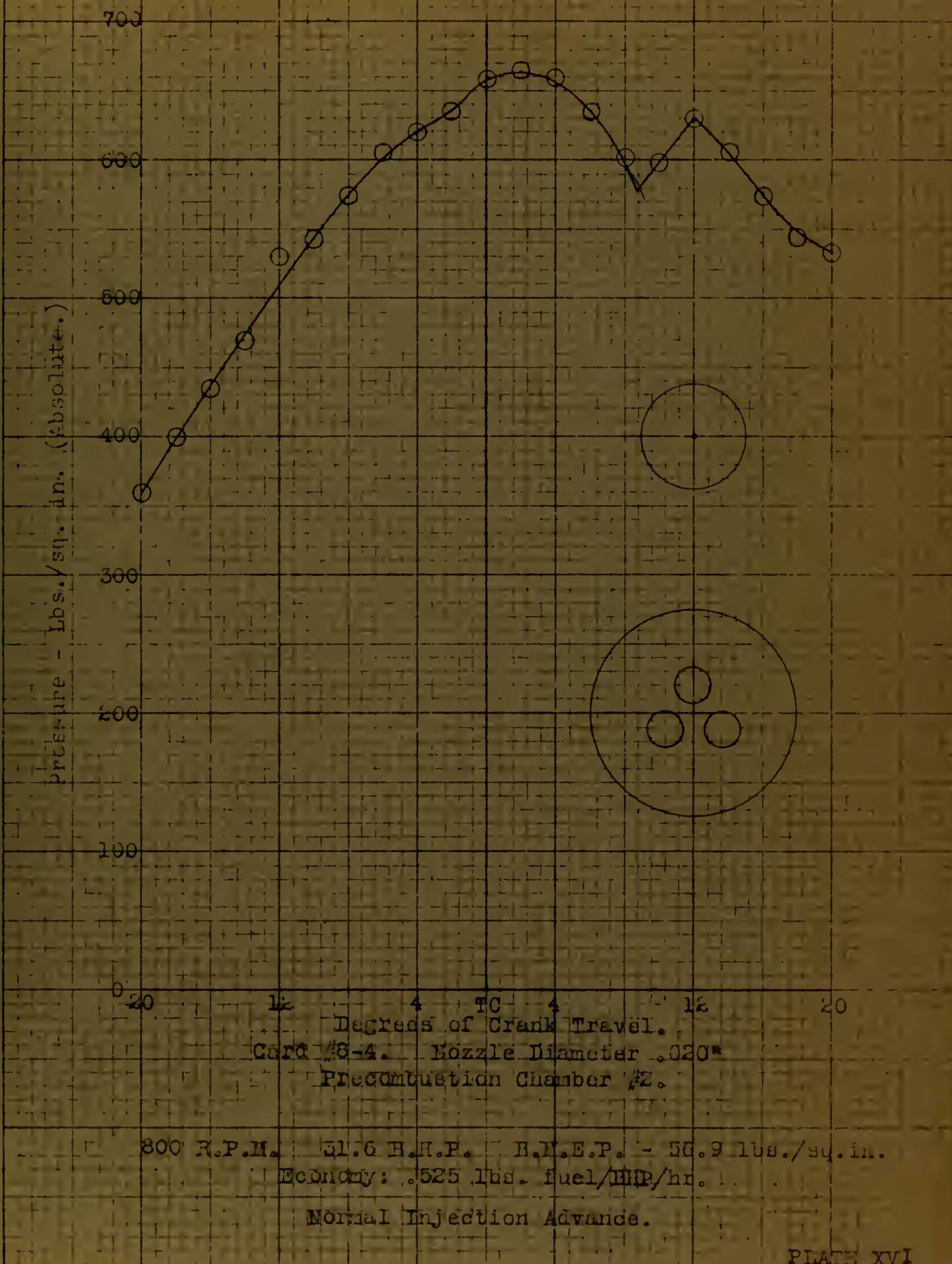




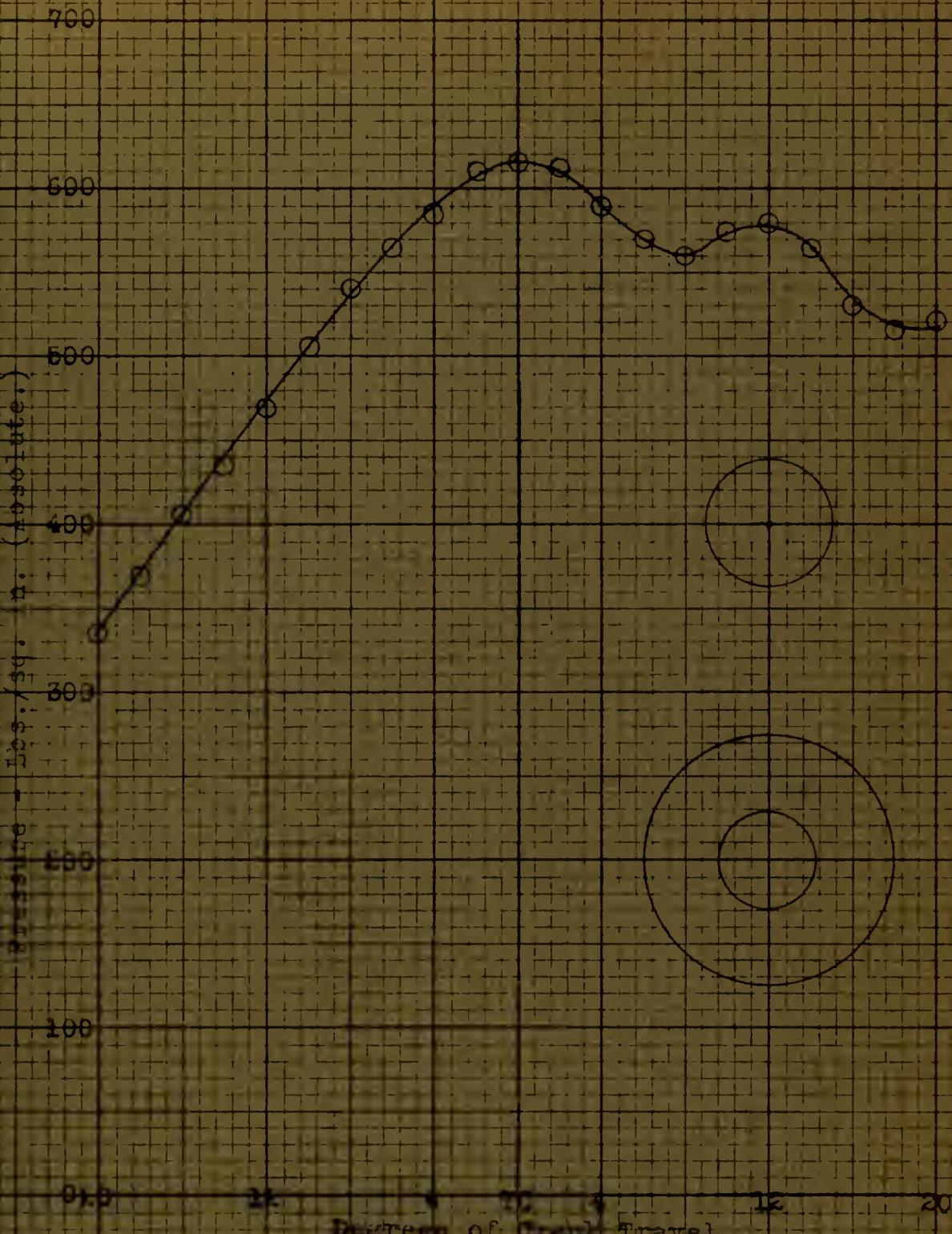
Card #7-3. Nozzle Diameter .020"  
Precombustion Chamber #3.

800 R.P.M., 31.6 B.H.P., B.M.H.P. = 56.9 lbs./cu. in.  
Economy: .527 lbs. fuel/BHP/lhr.  
NORMAL INJECTION ADVANCE.





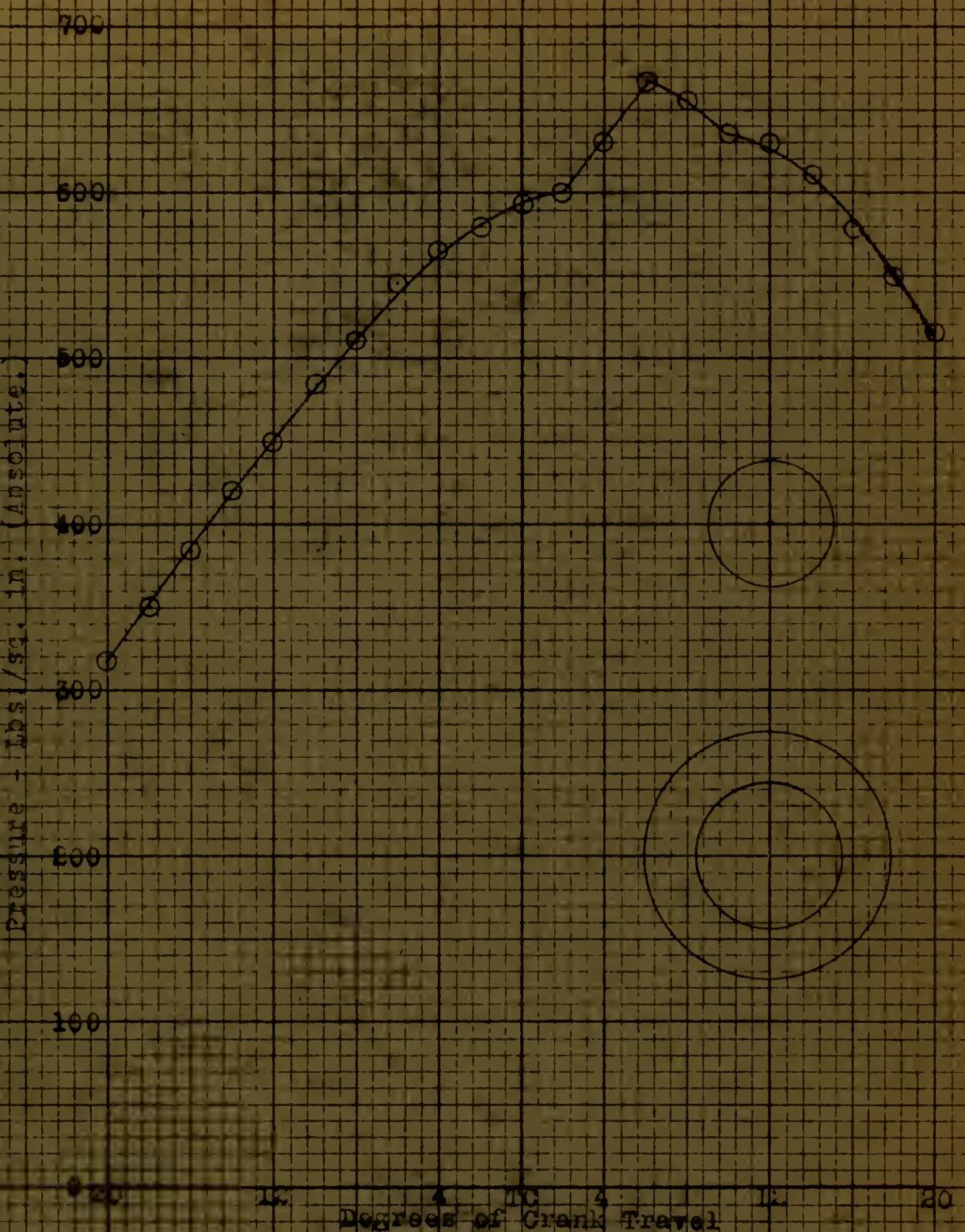




Card No. 1. NOZZLE Diameter .020".  
combustion Chamber #36.

T.C.P. = 50.9 lbs/sq.in.  
W.T. = 28.1 lbs. per cu. ft.  
Normal injection pressure.

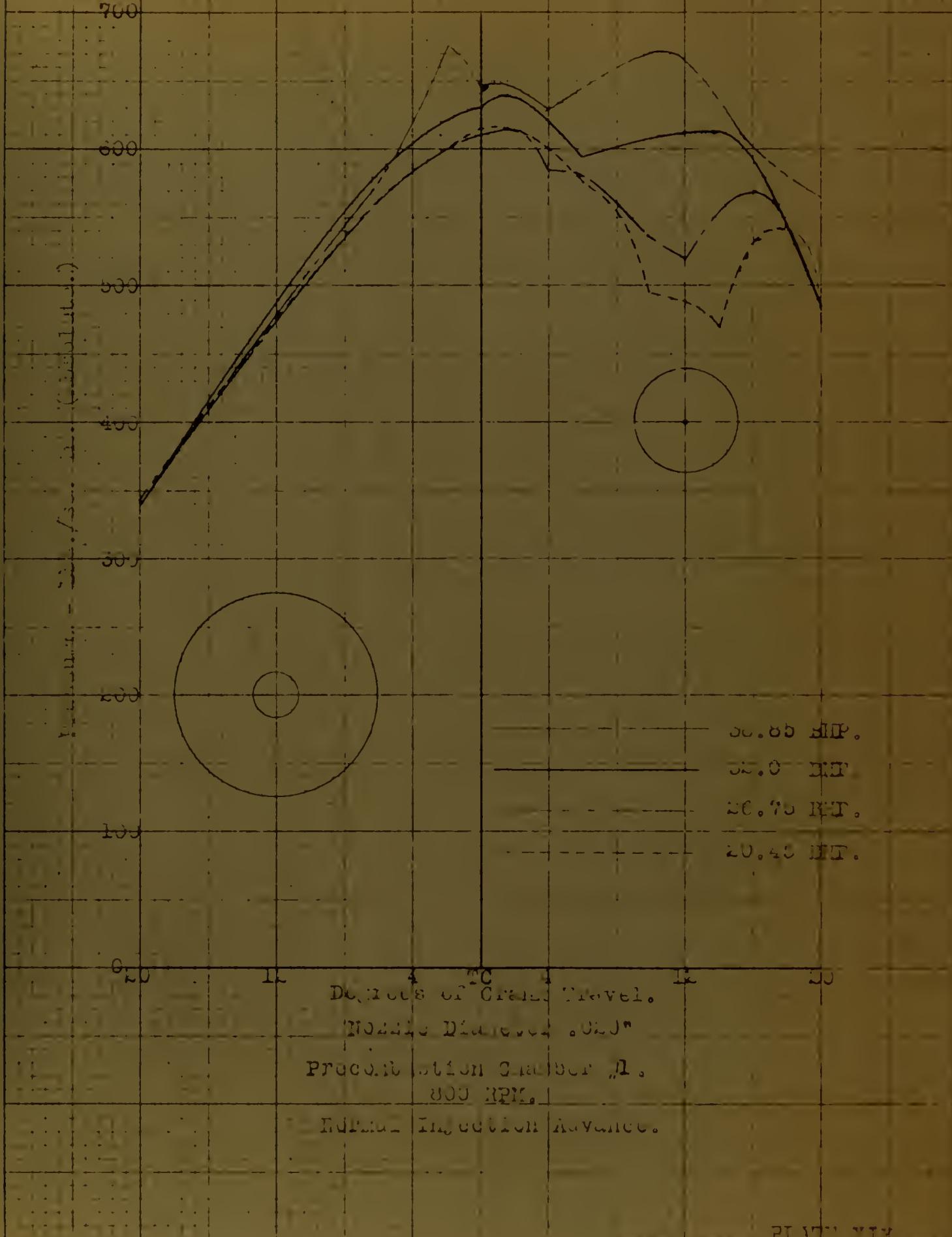




Case #10-5. Nozzle Diameter .020".  
Precircumcombustion Chamber #4.

S.I.P. 13.5 I.B.P. B.M.E.P. = 56.9 lbs./sq.in.  
Economy .005 lbs. fuel/I.B.P./hr.  
Advanced Injection.







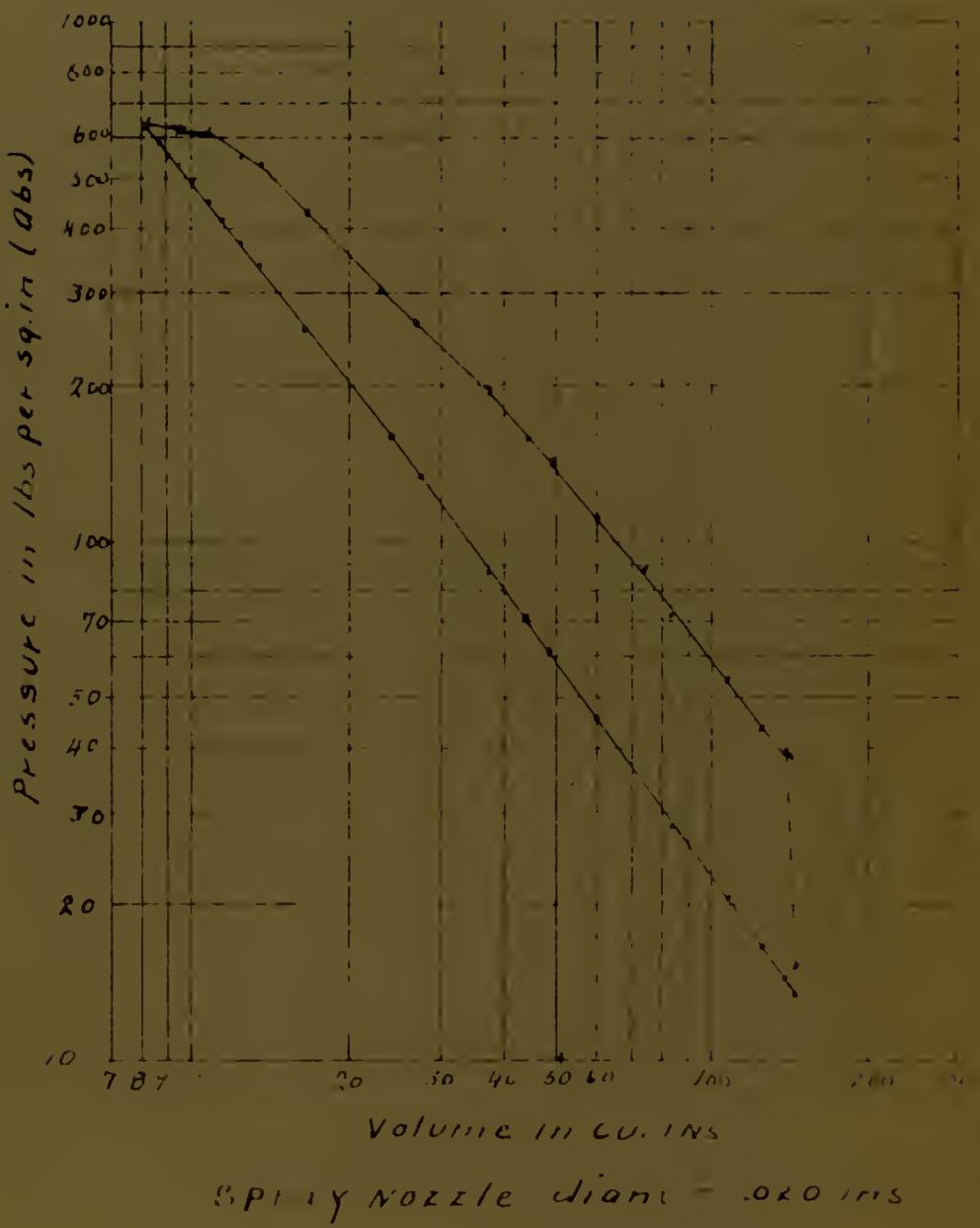
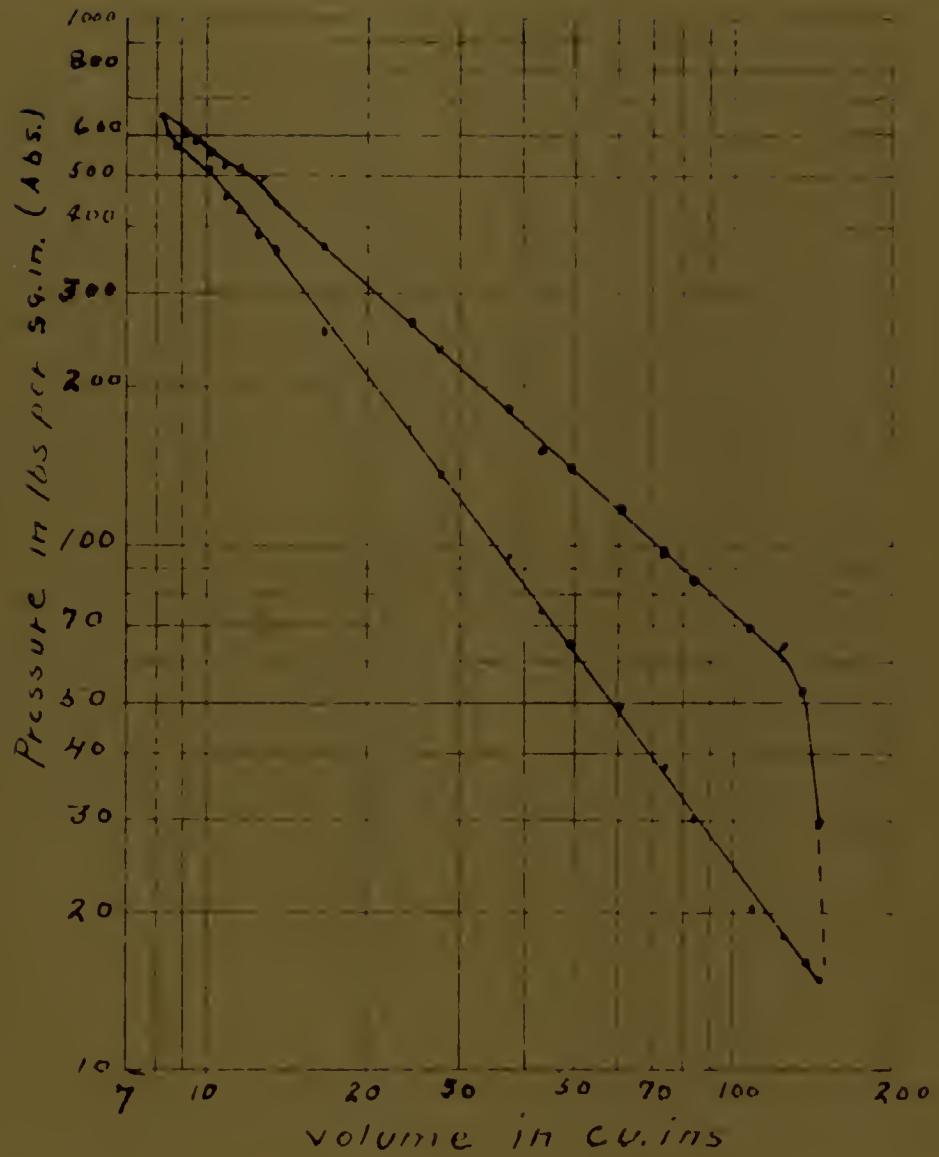


Plate XX





Spray nozzle diam. .010 in

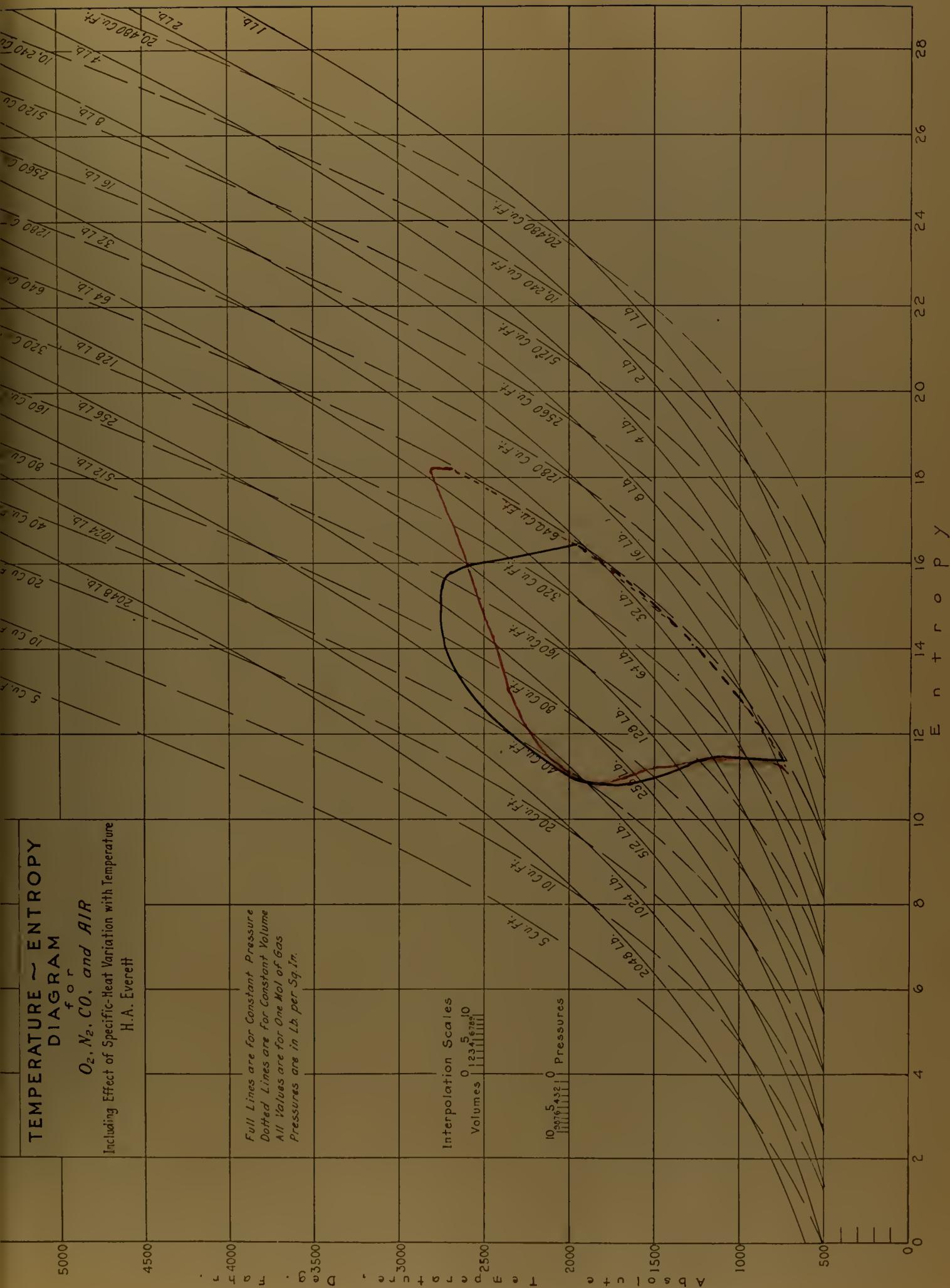
Plate XXI



# TEMPERATURE ~ ENTROPY DIAGRAM

*for*  
 $O_2$ ,  $N_2$ ,  $CO$ , and  $AIR$

Including Effect of Specific-Heat Variation with Temperature  
H.A. Everett





**PRESSURE INDICATOR (see Fig. 202, page 3)**









SECTION A-B

D-  
TIMER FOR INDICATOR







TRANSIENT DATA SOURCE



Offset Diagram Readings										
Crank Degrees	Card 1-3	Card 2-4	Card 3-2	Card 4-3	Card 5-5	Card 6-4	Card 7-3	Card 8-4	Card 9-4	Card 10-5
20	340	345	345	354	354	345	354	345	355	317
18	375	380	375	389	389	38	389	385	370	350
16	420	415	420	424	424	424	424	400	405	385
14	450	465	450	454	459	450	459	455	455	450
12	495	495	485	494	497	490	494	515	470	450
10	535	535	520	524	529	514	524	527	515	505
8	550	555	533	531	539	547	544	533	543	510
6	565	565	578	594	594	555	579	590	555	545
4	590	590	595	514	552	515	574	500	505	505
2	625	642	615	642	694	633	611	621	615	580
0	650	650	635	669	710	712	614	640	615	593
-2	642	645	635	704	719	720	611	620	612	590
-4	615	620	620	744	759	720	599	645	640	630
-6	595	620	590	724	774	705	574	620	570	607
-8	617	615	570	754	679	710	570	580	500	655
-10	615	595	540	729	757	685	594	583	575	635
-12	611	555	505	704	719	655	639	615	580	630
-14	612	535	400	699	694	625	599	590	555	610
-16	595	510	47	654	659	555	569	500	530	578
-18	545	480	383	594	619	540	544	500	515	550
-20	530	400	375	577	574	505	522	517	52	515
-26			475							

All pressures corrected for barometer, and  
zero indicator reading



Date	Run No.	Time		P
		Min	Sec	
March 7	1	47.		.715
	2	22.2		.517
	3	32.		.515
	4	39.1		.512
March 8	1a	26.8		.521
	2a	27.9		.511
	3a	41.55		.500
April 5	1	21.8		.623
	2	21.1		.618
	3	27.4		.600
	4	21.0		.600
	5	21.7		.605
April 12	1	31.9		.677
	2	31.5		.672
	3	27.4		.600
	4	24.1		.600
	5	20.3		.670
April 15	1	22.1		.600
	2	22.7		.67
	3	21.3		.542
	4	21.8		.564
	5	21.9		.567
April 19	1	19.0		.745
	2	21.6		.600
	3	21.1		.600
	4	21.0		.600
	5	21.7		.600



Date	Run No.	Time	Temp	Humidity	Wind
April 8	1	24.1	.734		
	2	29.0	.717		
	3	27.7	.742		
	4	31.0	.700		
April 20	1	29.9	.533		
	2	27.9	.513		
	3	21.0	.527		
	4	24.1	.500		7
	5	21.9	.517		
	6	27.4	.532		
	7	22.4	.590		
April 22	1	24.8	.523		
	2	24.1	.512		
	3	21.4	.505		
	4	21.0	.515		
April 23	1	24.8	.517		
	2	24.1	.519		
	3	27.4	.511		
	4	21.0	.518		
	5	34.9	.517		
April 26	1	24.1	.545		
	2	24.1	.514		
	3	23.8	.598		
	4	27.4	.502		10
	5	34.0	.558		
	6	24.9	.515		



## PRESSURE, VOLUME AND TEMPERATURE RELATION. TIPS

FOR .010 INCH NOZZLE

Temperature in degrees F. or D. C.	fraction of expansion	Displacement Volume + Clear- ance	$\frac{\text{Vol}}{\text{Mass}} = V$	V	Pressure Compression Stroke	Temperature Compression Stroke	Pressure Expansion Stroke	Temperature expansion stroke
0	.25	1.155	33.5	545	1020	525	125	125
2	.204	1.105	1.15	39.51	523	1950	535	1900
4	.1915	1.450	1.18	34.2	512	1950	520	1700
6	.1934	8.718	1.22	35.4	585	1930	585	1930
8	.1900	9.075	1.27	30.8	500	1920	505	1900
10	.1992	9.52	1.35	38.0	500	1900	570	1740
12	.1955	10.11	1.415	41.0	502	1920	525	174
14	.1882	11.75	1.505	42.6	400	1770	525	2100
16	.1238	11.52	1.601	40.0	425	1250	510	2200
18	.1100	12.38	1.73	50.2	385	1500	495	231
20	.0907	12.30	1.80	54.0	360	160	440	2210
25	.0545	10.33	2.28	80.1	250	1570	305	225
30	.114	23.95	3.35	97.1	155	1545	265	240
40	.140	27.50	3.85	111.5	137	1400	225	240
50	.2115	37.35	5.22	151.5	94	1220	180	2500
56	.2500	44.05	6.17	179.	74	1175	150	25
60	.2920	46.35	6.70	190.0	65	1120	140	2500
70	.3770	50.35	9.45	244.1	48	1055	117	3000
80	.4077	72.05	13.2	290.	38	1035	97	3070
90	.5563	84.75	11.8	342.	30	910	85	2700
110	.7200	1.7.45	15.01	436.	20	832	59	2820
130	.8542	124.25	17.4	510.	18	775	50	2820
150	.9409	130.45	19.4	504.	16	760	52	2720
180	1.000	145.75	20.3	590.	15	740	29	



PRESSURE, VOLUME AND TEMPERATURE RELATIONSHIPS  
FOR .050 INCH NOZLE.

Degrees From Top D. C.	Friction of Stroke	Displacement Volume + Clear- ance	$\frac{V}{Vol}$	V	Psi. Cylinder Pressure	T Cylinder Temp.	T Cylinder Temp.	T Cylinder Temp.	T Cylinder Temp.
0	0	8.55	1.115	..	100.0	130.0	130.0	130.0	130.0
2	.0004	8.505	1.11	5.11	100.0	105.0	105.0	105.0	105.0
4	.0015	8.487	1.11	64.2	500.0	117.0	117.0	117.0	117.0
6	.0034	8.712	1.11	75.4	500.0	135.0	135.0	135.0	135.0
8	.0060	9.075	1.07	38.8	500.0	160.0	160.0	160.0	160.0
10	.0095	9.32	1.03	38.6	500.0	162.0	162.0	162.0	162.0
12	.0135	10.11	1.41	1.0	500.0	165.0	165.0	165.0	165.0
14	.0182	10.70	1.05	47.0	444.0	170.0	170.0	170.0	170.0
16	.0228	11.11	1.01	46.0	416.0	162.0	162.0	162.0	162.0
18	.0260	11.31	1.07	30.8	274.0	170.0	170.0	170.0	170.0
20	.0297	11.30	1.03	54.0	274.0	170.0	170.0	170.0	170.0
26	.0595	11.17	1.07	20.1	274.0	160.0	160.0	160.0	160.0
36	.114	72.00	1.05	97.1	100.0	100.0	100.0	100.0	100.0
40	.140	77.00	1.05	111.8	100.0	100.0	100.0	100.0	100.0
50	.211	77.0	1.05	177.0	200.0	100.0	100.0	100.0	100.0
56	.2600	77.0	1.07	17.0	70.0	100.0	100.0	100.0	100.0
60	.2320	77.0	1.05	196.0	100.0	110.0	110.0	110.0	110.0
70	.3786	60.50	1.05	54.1	47.0	100.0	111.0	111.0	111.0
80	.4677	77.65	10.0	1.0	100.0	100.0	100.0	100.0	100.0
90	.5567	77.70	11.0	2.0	100.0	910.0	910.0	910.0	910.0
110	.7906	107.00	11.01	6.0	100.0	100.0	100.0	100.0	100.0
120	.8544	114.20	17.4	1.0	100.0	100.0	100.0	100.0	100.0
150	.9403	114.50	19.4	0.6	100.0	700.0	700.0	700.0	700.0
180	1.000	145.75	10.0	0.30	100.0	100.0	100.0	100.0	100.0















AUG 31

BINDERY

Thesis 6312  
L8 Longstaff

AUTHOR

Use of indicator diagrams in  
TITLE studying combustion in a  
diesel engine.

DATE LOANED	BORROWER'S NAME	DATE RETURNED
		18

Thesis 6312  
L8 Longstaff

Use of indicator diagrams  
in studying combustion in a  
diesel engine.

DR FRANK  
1966 LIBRARY  
U.S. NAVAL POSTGRADUATE SCHOOL  
MONTEREY, CALIFORNIA

Bindery  
U. S. Naval Postgraduate School  
Monterey, California

thesL8

Use of indicator diagrams in studying co



3 2768 002 12639 3

DUDLEY KNOX LIBRARY